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ABSTRACT

Presented are six papers on water conservation which were presented at a conference in New Jersey. The first two papers present recommendations of the New Jersey Department of Environmental Protection on water conservation and a master plan for New Jersey's water supply needs. The following four papers discuss water conservation with water-saving devices, the impact of home water-saving toilets on wastewater collection and treatment, the potential for energy savings through reductions, through the use of flow reducing devices and other conservation methods, and the impact of water-saving devices on the water supply and drainage systems within buildings. (BB)

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Extension Bulletin 421

WATER
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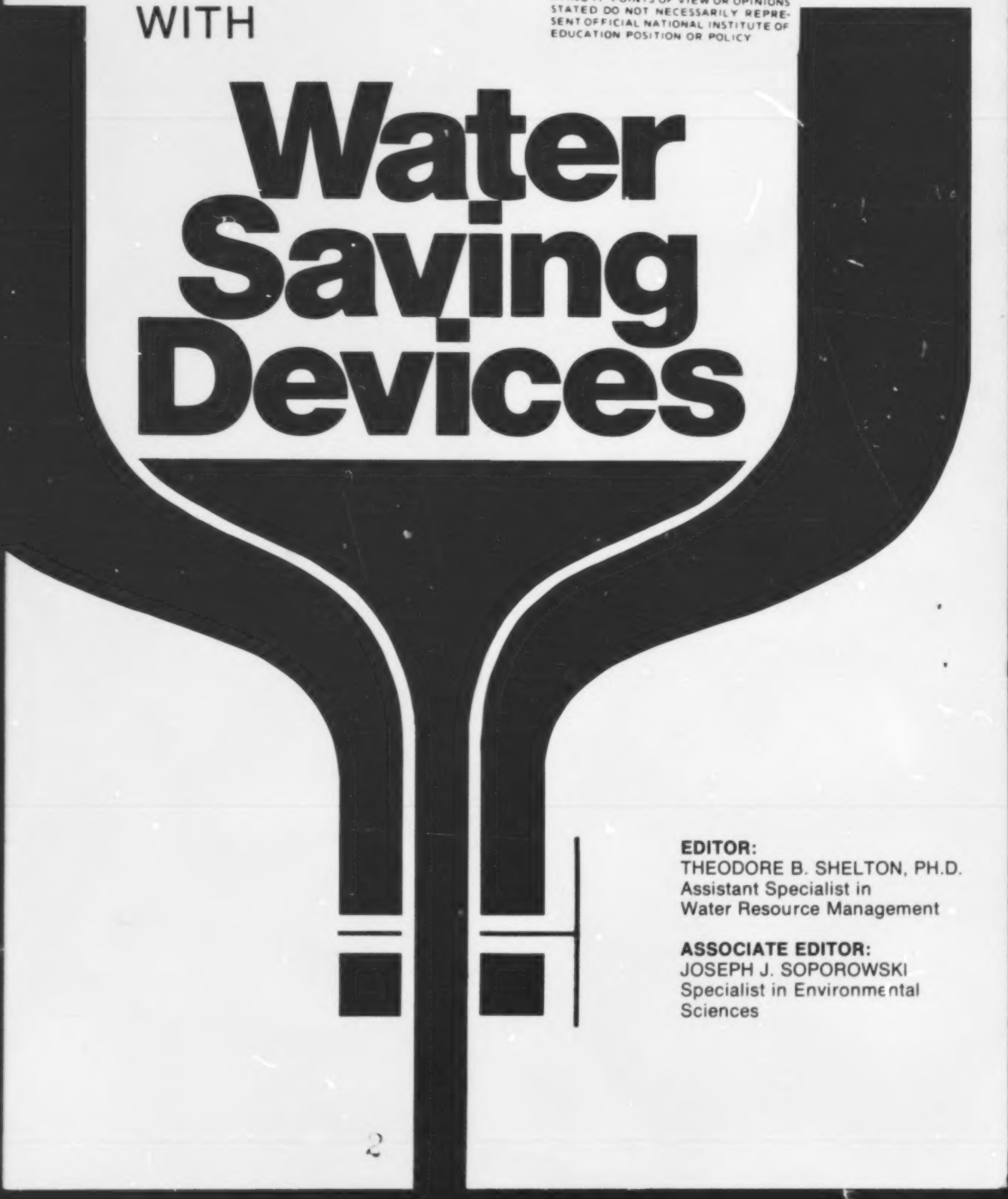

Water Saving Devices

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WATER CONSERVATION WITH WATER SAVING DEVICES

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New Jersey Builders Association

NOVEMBER 30, 1976

Lewis M. Herrmann Labor Education Center
Cook College, Rutgers University
New Brunswick, New Jersey 08903

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Introduction and Summary of Proceedings

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The N.J. Conference on Water Conservation with Water Saving Devices was held on November 30, 1976, at the Lewis M. Herrmann Labor Education Center, Cook College - Rutgers University, New Brunswick, N.J. 08903. The conference was convened in response to concern about the need to introduce water saving devices to the citizens and the leadership of New Jersey. The N.J. State League of Municipalities, N.J. Plumbing Inspectors Association, N.J. Chapter of the American Water Works Association, and the N.J. Builders all endorsed the conference and their membership was well represented. In addition, over 300 participants representing a spectrum of concern for water conservation were in attendance. Nine manufacturing firms displayed their products and devices in the exhibitors' area.

The proceedings of this conference will be distributed to each of the participants and a limited quantity will be available to other interested parties. The presentations are expected to be useful references for municipal officials, planners, consulting engineers, college and university facultys, and interested citizens.

The morning session was introduced by Grant F. Walton, Dean, Cook College, who welcomed the group to the campus and outlined the need to conserve water.

In developing this theme, John Wilford of the State Department of Environmental Protection facilities, used the example of England, which experienced its greates drought on record this past summer, to show the consequences of no significant rainfall on the population. A similar drought here in the Northeast is always a possibility, he said.

The fastest growing cost item on the nation's water budget is the energy needed to pump water from one place to another. In domestic water heating for the homeowner, the cost of energy used to heat the water is greater than the cost of all the water used in many areas in the United States. On a national basis, domestic water heating alone consumes 4 percent of our total energy budget. Therefore, saving water saves energy.

Homeowners with individual on-site sewerage treatment systems can often postpone extensive replacement costs by simply reducing the amount of water consumption in their homes.

Less water consumed means less sewage produced. This may influence lifting of sewer-hookup moratoriums in many communities in N.J. By reducing sewage flow, sewage treatment costs for operation and construction will be reduced. In a growing number of municipalities, the cost of sewage treatment is being billed directly to the homeowner as a percentage of the water bill; this makes it doubly clear that reducing water consumption reduces costs to the homeowner.

Voters and lawmakers are becoming sensitive of environmental concerns. It is becoming increasingly difficult to create "new" water by damming wild or scenic rivers or diverting waters from one drainage basin to another – the Tocks Island Dam is a good example here in N.J.

In most areas of the country, the most easily exploited water sources have already been developed; tapping each new source will be more costly and complicated than the last one.

Wilford said that though there is much room for conservation measures in manufacturing and industry, most water use and waste occur in the home. More than half the water used in the home could be conserved by installing water-saving toilets and showers. These plumbing fixtures are already on the market, but an amendment to the National Standard Plumbing Code would be required in order for such installations to be made mandatory in N.J. Appropriate recommendations have already been made to the code-writing committee by the State.

The Department of Environmental Protection's recommendations for water conservation were also discussed in detail by Wilford.

William Whipple, Director of the N.J. Water Resources Research Institute, discussed the formulation of a master plan for the state's water supply. The plan, which was authorized last year, would provide information on where water reserves are in the state, what the needs are, and would develop contingency plans in case of a major drought. The two major problems which have to be addressed in any plan that emerges are how to deal with periodic droughts and how to preserve the quality of the water we do have. This is the first time N.J. has ever had such a comprehensive planning.

Pennsylvania State University, discussed specific water saving devices which can be used in the home through a series of slides.

The public has long viewed the supply of water as inexpensive and inexhaustible. It is only when a severe water shortage occurs or a sewage system becomes overloaded, resulting in moratoriums on new sewer hookups or construction, that consumers become concerned about water conservation. Even then, attempts to correct the situation are often directed towards seeking new sources of water, improving existing distribution systems, treatment facilities, and the like, and not towards the physical conservation of the water supply. This attitude should be kept in mind as it is an important consideration that must be resolved before any conservation program can begin.

Conservation of water used in the home, unlike efforts to conserve electrical energy and save heating fuel, does not require a change in individual lifestyles or habits. Unlike expensive pollution control equipment, the simplest water conservation devices cost under $1, and even the most expensive are cost effective and pay for themselves over time. A 1969 survey by the General Dynamics Corp. indicated that people will reject flow reduction devices which have high initial cost, require operational maintenance, and lack esthetic appeal.

Bricks and plastic bottles have been used to save water in flush toilets that were originally designed to use more water than necessary for adequate flushing. A plastic bottle, weighted down with a small stone, is probably a better technique as there is a chance of breaking or chipping the bowl if a heavy brick is used. The objects merely displace the water which would ordinarily be flushed. A saving of up to 2 quarts per flush is possible.

It is usually not a good idea to bend the float arm down to save water, although this can be done. This technique decreases the force with which water moves through the toilet bowl and may [illegible] the need for an extra flush.

Commercial toilet reservoir volume reducers are also available. These devices displace a section of the toilet reservoir, cost a few dollars, and are easy to install.

Faucet aerators, already in wide use, are another means of saving water. Faucets with aerators provide a nice even flow and reduce splashing. By mixing water with air, they reduce the amount of water flowing from a faucet. The air added to the water as it leaves the faucet makes a stream of air and water. This gives the illusion that more water is flowing from a tap. When water is left running to wash something, as in rinsing dishes or washing one's hands, less water is actually used. Faucet aerators are easy to install and quite inexpensive.

water-saving devices. These taps are actually mini-showers designed for use in lavatory sinks and wash basins. Water is not sprayed from the tap in a single stream as is the case with conventional faucets. The spray allows for faster washing and rinsing with less water use. When such devices are combined with mixing valves, water savings of up to 90 percent are claimed by the manufacturer, according to Sharpe.

Flow control devices are another means used to conserve water by limiting the rate of flow from shower heads and faucets. These devices are usually nothing more than valves that fit into the water lines of faucets or showers. Flow is usually limited to 2.5 gallons per minute from faucets and 3 gallons per minute from showers. Normal flow from showers varies between 5 to 15 gallons per minute. Water savings of 50 to 70 percent are claimed for flow-limited shower heads and up to 50 percent for faucets. Assuming average shower usage, more than 2,000 gallons of water may be saved per person per year. A similar type of device is the thermostatic mixing valve. These valves permit mixing of hot and cold water to preset temperatures. Water issues from the tap at this temperature. In this manner water is not wasted while its temperature is being adjusted by manipulating the hot and cold water faucets. Substantial savings can be achieved with flow-limiting devices in shower heads. Shower heads with built-in flow controls are also available from several companies.

Shallow trap or water-saver toilets are now being manufactured in this country as a result of establishment of a federal specification. They are required by local plumbing codes in some areas of the east, i.e., Washington Sanitary District. The principal feature of this type of toilet is a smaller water reservoir than that of a conventional toilet. These toilets use less than 3½ gallons per flush as compared to 5 to 6 gallons for a standard toilet. This amounts to a savings of 7½ gallons per day for the average person. Shallow trap toilets are operated the same way as conventional toilets and are no different in appearance.

John G. Muller of the Federal Energy Administration outlined the various potential savings in conserving heated water. There is very little data available on how Americans use their heated water. This is certainly an area in need of further research. Our best estimate is that residential water heating accounts for an energy consumption of 1.1 million barrels per day (BPD) oil equivalent today but this energy use could be cut sharply. There exists a potential savings in excess of 500,000 BPD obtainable without adverse effects upon our health, comfort, or lifestyle. The biggest potential savings is offered by the following measures: (a) replacement of existing water heaters over a period of years with more efficient heaters; (b) adoption of cold-water laundering using improved detergents; and (c) use of flow reductors in shower and basin faucets. Given adequate inducement, manufacturers are capable of carrying out the research and development program necessary to make the needed improved products available. The most difficult task is to motivate the individual to adopt the energy saving measures and to make available some economic incentive, but still the potential for energy savings through the use of flow reducing devices and other conservation methods exists. A realistic goal is 50 percent of the potential.

Thomas P. Konen gave a preliminary assessment of the impact of water-saving devices on the water supply and drainage systems within buildings; this is part of continuing research at Stevens Institute of Technology. Water-saving fittings, fixtures, and other devices influence the magnitude of the demand, the volume of water consumed, and in some instances may effect the performance of the drainage system. He examined the significance of this influence on the plumbing systems, within multi-family and commercial buildings. The scarcity of data on parameters, such as frequency of use, and the limited knowledge of complex multi-phase flow in the drainage systems, makes most of the assessment preliminary.

The audience was very enthusiastic and responsive to the information presented at this conference. Many participants expressed the desire for a followup conference to assess N.J. progress in water conservation with water-saving devices. The conference was considered highly successful in reaching the key leadership in the state.

Recommendations of the N.J. Department of Environmental Protection on Water Conservation

by
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NEED FOR WATER CONSERVATION

The summer of 1976 brought unprecedented drought conditions to most of Western Europe. In Britain, for example, rainfall was the lowest since recording procedures were established 250 years ago and resulted in critical depletion of reservoirs. The Yorkshire Water Authority, which serves my native city of Leeds and surround areas, made plans initially for cessation of water service for 12 hours each day and, secondly, cutting off supply to individual homes and erecting over 9,000 temporary faucets in the streets from which householders could haul their water in buckets.

England is at a convenient distance of over 3,000 miles - convenient, that is, for us to forget that nature, with typical capriciousness, could inflict similar problems upon us. Closer to home, several of the Midwest farm-belt states suffered extensive droughts this past summer. Fortunately, the drought area did not include any large centers of population so, although there was some impact on crop production, it did not result in serious shortages of water supply.

The passage of time has dulled the memory of the several-year drought which occurred in the North-eastern States, including New Jersey, in the early 1960's. This resulted in serious difficulties in providing an adequate supply of water to the various purveyors who serve the densely populated metropolitan area of this state. Maintenance of supply was accomplished by manipulating the interchange of water from various reservoirs through fortuitous interconnections and the transmission mains of cooperating purveyors, and by augmenting reservoirs with water pumped from lakes, together with a reduction in water use by a cooperative public. The situation was far more critical than the public realized. Although the immediate crisis has passed, a potential for disaster still exists because the safe yield of water continues to be exceeded.

In "Water Supply Management in New Jersey," dated April 1975 and published by the County and Municipal Government Study Commission, it is pointed out that New Jersey's water supply system was in better shape going into the 1960's drought than the present system would be in the event of a similar drought.

In 1973 the water purveyors in the Passaic and Hackensack River Basins supplied an average of 399 MGD from their surface water reservoirs while they had a safe sustained yield of only 366 MGD, a daily gap of 33 million gallons. The gap widened from a virtually balanced system to this deficit in a six-year period. The deficit in system safe yield for the Newark, Jersey City, and Hackensack systems approximately 60 million gallons, and enormous shortfall that is greater than the safe sustained yield of Newark's entire Pequannock Reservoir System.

The recent economic recession and adequate rainfall has provided temporary relief, so the deficit was reduced to approximately 24 MGD during 1975. We cannot, however, afford to be complacent. The economy is on the upturn, population continues to increase, and there is growing use of domestic water. The cyclical records of rainfall indicate the inevitability of another drought period when winter rainfall will be insufficient to fill the reservoirs and New Jersey's population and economy will be again threatened by water shortages.

Some attempt is being made to develop new sources of water for the thirsty northeastern area of New Jersey. Because the state is highly developed and populated and there are few sites left which could be economically developed for large-capacity reservoirs, these new sources cannot wholly overcome the deficit in safe yield, particularly if water demands continue to increase.

The growth of urbanization and increased water usage has also had an impact on sewage treatment facilities. There are currently over 60 sewerage connection bans in force partly or wholly affecting over 100 municipalities because sewage treatment plants are over their design capacities. The cost of providing new sewage treatment facilities exceeds $400 million yearly in New Jersey, much of this being required to rectify hydraulic overloading.

There is thus compelling need for water conservation practices to hold down the increases in water demand or, better still, to reduce current demands.

Industrial and commercial demands for water are probably in excess of real needs and, obviously, cannot be disregarded. There is certainly much room for better water conservation practices by such users through economies and greater recycling encouraged, perhaps, by a revised pricing structure which changes the current prevalent practice of reducing the unit cost of water as the volume used increases. Nevertheless, it is the domestic user who, cumulatively, accounts for the greatest volume of water used in the average water supply system.

Various estimates have been made relative to the proportions of water used for differing purposes in the average household. There is obviously significant variation due to climate, type, and age of plumbing fixtures, location, type, and age of the home, personal habits and socioeconomic factors. Following however, is a table developed by the U.S. Geological Survey to describe annual domestic water consumption in Akron, Ohio. These figures are believed reasonably typical of the average dwelling.

Toilet Flushing	41%
Bathing	37%
Cooking and Washing	9%
Drinking	5%
Clothes Washing	4%
Lawn Sprinkling	3%
Car Washing	1%

From the above, it is apparent that the most meaningful water conservation measures should be directed to reductions in use for toilet flushing and bathing and, to a lesser extent, for cooking and washing, all of which have impact on the volumes of water needed to be produced by a public water supply system and on the needed capacities of sewerage systems and sewage treatment plants.

The average toilet uses about 5½ gallons per flush, though many older models use as much as 8 to 10 gallons. A modest reduction in the water use per flush, particularly in the larger tanks, would not have a significant impact on the flushing ability of the bowl. It is generally accepted that a flushing volume of 3½ gallons is adequate for the average toilet. Assuming an average household of four persons, four flushes per day per person and 5½ gallons per flush, by reducing the flushing volume to 3½ gallons a saving of 32 gallons per day per home, or almost 11,700 gallons per year could be effected.

Studies have shown that of the personal bathing use of 37 percent of domestic water consumption, 60 percent is represented by shower baths. Test data compiled by a plumbing equipment manufacturer shows that different makes of shower heads use between 1.5 and 9.5 gallons per minute at 20 psi and full flow, with a mean of 5 gpm. A controlled test conducted by the Washington Suburban Sanitary Commission has demonstrated that the installation of shower flow controls and shower heads which limit the volume of water to 3 gpm can reduce the per household water consumption by approximately 12 percent. Extrapolating this on the basis of an average total domestic usage of 85 gallons per capita per day, water savings in a home with four occupants could amount to approximately 41 gallons per day, or 14,900 gallons per year. Saving of water represented by other uses would be of lesser magnitude and would depend, to a great extent, on personal habits. Nevertheless, the cumulative effect of utilizing water economy faucets, dishwashers, and washing machines, combined with a successful educational campaign would be significant. Reduction in water use can also be effected through the economic impact of water meters, though the resultant savings by this means should not be overestimated.

REQUIREMENT FOR WATER CONSERVATION PLUMBING THROUGH THE PLUMBING CODE.

On October 7, 1975, the New Jersey State Uniform Construction Code Act was signed into law. This empowers the Commissioner of the Department of Community Affairs to promulgate a statewide construction code which will supersede a myriad of existing local and state codes. The construction code will comprise component subcodes, including one for plumbing.

The adoption of a subcode for plumbing offers an excellent opportunity to require the installation of water conservation fixtures in new buildings. If such a requirement can be embodied, it will do much to reduce per capita demands for water. The overall reduction would not be immediate because of the millions of existing structures in New Jersey presently equipped with standard plumbing fixtures. There would, however, be an immediate impact on new structures and, at the estimated average replacement rate of 2 per annum, virtually all existing toilets (which use a larger percentage of water than any other plumbing fixture) would be replaced within fifty years.

The subcodes must be adoptions of national model codes. The Department of Community Affairs plans to adopt the National Standard Plumbing Code promulgated jointly by the Association of Plumbing-Heating-Cooling Contractors and the American Society of Plumbing Engineers. The enabling Act restricts supplementation or revision of an adopted national code. Howeve, future amendments to any national code that is adopted will automatically become part of the construction code.

The quoted National Standard Plumbing Code does not make providion for the installation of water conservation plumbing fixtures. Thus, in order for such installations to be made mandatory in New Jersey, an appropriate amendment will be needed, either by a specific requirement that all newly-installed or replacement fixtures shall be of the water conservation type, or as an alternate that can be adopted by participating agencies. The probability of the former seems remote, so the latter appears to be the most feasible.

Appropriate recommendations have already been made to the Code-writing Committee, and the writer and a representative of the Department of Community Affairs recently attended a public meeting of the committee to explain the reasons for New Jersey's request. The request was for the inclusion of a new permissive section in the code which specifically deals with water conservation plumbing, suitably designated to indicate that it is subject to local change or adoption. This could then be adopted by the Department of Community Affairs, by regulation, on the basis of adequate justification of New Jersey's unique problems dictating the need for water conservation, requiring the immediate installation of water conservation plumbing in all new structures and, after a date to be determined, the installation of such plumbing in existing buildings when replacements of older units become necessary.

An equitable date for mandating the needed replacements of existing fixtures with those of the water conservation type is necessary to allow for the depletion of stocks of standard fixtures presently held by plumbers and plumbing warehouses throughout the state, and for manufacturers to gear up for the production of an adequate number of water conservation fixtures.

WATER CONSERVATION REQUIREMENTS IN DEPARTMENTAL PERMITS, ETC.

A suggestion has been made that, by local ordinance, the installation of water conservation devices be required when a sewer connection ban is to be modified or lifted, as a prerequisite to the approval of the Department of Environmental Protection for a federal grant for wastewater treatment facilities, and for all approvals regarding new water supply facilities (including new diversions or wells) and for sewer extension permits. However, as specifically provided for in the State Uniform Construction Code Act, such local ordinances will be preempted when the State Uniform Construction Code is adopted.

A more meaningful approach would be to include requirements for the installation of water conservation plumbing in appropriate permits issued by the department, even though they would be difficult to enforce.

The recently promulgated Sewerage Connection Ban Regulations include a requirement that an applicant for an exemption must, inter-alia, submit a plan for water conservation plumbing. It should be emphasized that the requirement applies only to an individual exemption, and is not currently required as a condition for the lifting of a ban. The Water Pollution Control Monitoring, Surveillance and Enforcement Element, which administers the regulations, lacks the manpower to follow up the requirement to assure that water conservation plumbing has been installed, this being left to local officials. Nevertheless, the requirement has excellent impact in emphasizing the need for water conservation.

The latest draft of proposed Rules and Regulations for the administration of New Jersey's Coastal Area Facilities Review Act includes a requirement that, "The utilities plan shall include a strategy for water conservation, including techniques for recycling of water." The "utilities plan" does not refer to the utilities themselves, (e.g., water purveyor, sewerage authority) but to the manner in which those utilities are used within the structure or structures for which a permit is sought. The term "water conservation strategy" is not defined, so it is suggested that an appropriate definition, to include water conservation plumbing, be incorporated.

Similar requirements for the installation of water conservation plumbing in new structures could be incorporated into other permits issued by the department, specifically those for water diversion rights, new public water supply systems, water main extensions, new public wastewater treatment plants, and sewer extensions. The utilities to whom the permits are issued rarely have direct jurisdiction over the type of plumbing fixtures and devices installed in new construction, so the plumbing inspector is the logical individual with responsibility for enforcement.

WATER METERS

Economic theory predicts that the consumption of water will decline if it is metered and charges are directly proportioned to the amount used. Several studies, however, have shown that in-house use of water does not decline in metered areas within the usual range of water costs because there is no substitute for its in-house use and, irrespective of water conservation practices, there is traditionally a minimum quarterly charge for a volume of water which is adequate for normal domestic needs. Meters nevertheless encourage a faster repair of leaks, and they do result in a lesser use of water for lawn sprinkling, car washing, and the filling of backyard swimming pools. In approving diversion rights for public waters supplies, the current approvals of the Water Policy and Supply Council require that all services shall be metered. Where meters are not presently installed on all services, they are required on all new construction and a plan must be submitted to the council for the ultimate metering of all existing services. The diversion right permit provides for its revocation in the event of on-compliance with its conditions. If non-revoked, the water purveyor would then be in violation of the stature by reason of not having a valid permit.

Except for revocation of diversion rights, which is more psychological than meaningful because water service to existing consumers obviously cannot be curtailed or suspended, the council has a little legal redress. The statute, under which the Water Policy and Supply Council is established and operates, makes no provision for enforcement and penalties other than for violations of stream encroachment and private diversions of surface water. This is a serious deficiency which erodes the effectiveness of the council and the department in their water-apportionment obligations.

Nevertheless, since the inception of the metering program about 15 years ago and its inclusions in diversion permits, several water purveyors have been subjected to hearings because of noncompliance and, in each case, the metering orders have been sustained or amended. The metering requirement has been upheld by the courts.

PUBLIC EDUCATION IN WATER CONSERVATION

To be successful, a public educational campaign to encourage the conservation of water, both by the modification of personal habits and by the installation of water conservation plumbing fixtures and devices, must be on a continuous basis rather than a "one-shot deal."

The following is quoted from a report, "Measures to Reduce Water Consumption in Southeastern New York," published November 1973 by the New York Temporary State Commission.

To be effective in the long run, an educational program should not be crisis oriented but should be designed to change basic attitudes. The scope of water supply problems, the alternatives available to meet the supply needs, and the cost of projects should become part of the public's understanding. The costs of structural projects including environmental and esthetic costs should be presented. The important role of non-structural approaches should be explained.

The educational program should be a long-term program with many small messages rather than a few intense ones. The direction should not be toward water use restrictions but toward the most efficient utilization of the water supply investment. One possible vehicle might be small pamphlets enclosed with each water bills similar to the material enclosed with other utility bills.

The long term public education program should explain the possibilities of water use reductions through water saving devices. It should be made clear that although new water saving devices are more expensive than traditional designs, their use will lead to smaller water bills for customers. The public should be encouraged to install water saving devices in new structures, or when replacement of older units becomes necessary.

We concur with these sentiments and recognize that, to be effective, a water conservation program must receive the support of the public.

D.E.P. RECOMMENDATIONS FOR WATER CONSERVATION IN NEW JERSEY

The New Jersey Department of Environmental Protection is convinced that an intensive water conservation program is essential for the continued economic and public health well-being of the State. It, therefore, has embarked upon such a program which will include all or most of the following elements.

1. As previously mentioned, continue the endeavors to have a new section included in the National Standard Plumbing Code providing for the installation of water conservation plumbing fixtures.
2. Define "water conservation strategy" in the proposed Rules and Regulations, to be promulgated pursuant to the Coastal Areas Facilities Review Act, to include reference to the installation of water conservation plumbing.
3. Include requirements, in permits for water diversion rights, new public water supply systems, water mains extensions, new public wastewater treatment plants and sewer extensions, for the installation of water conservation plumbing in new structures that will be connected to the works for which the permits are issued, and furnish the local plumbing inspector with a copy of the permits.
4. More vigorous pursuit by the Water Policy and Supply Council to require the speedy installation of water meters.
5. Develop a comprehensive public information program to encourage the conservation of water and the adaption of existing water using fixtures so as to use less water. This should be on a continuous basis, rather than a single endeavor. The program would be led by the department through its public information facilities, and include the following components:
   a. Encourage major water purveyors to enclose appropriate materials with their quarterly bills, and to otherwise advise their customers of the availability of water conservation plumbing fixtures and devices and the need to practice personal water conservation.
   b. Enlist the support of various trade and professional organizations, such as the plumbing manufacturers' trade association, the plumbers' trade union, New Jersey Builders Association, South Jersey Builders Association, Shore Builders Association, Health Officers Association, and Plumbing Inspectors' Association.
   c. Enlist the support of teachers of social studies courses in primary and secondary schools to disseminate information on water conservation practices to children. Encourage the instructors in vocational-technical schools that have plumbing courses to provide information to their students on the availability of water conservation plumbing.
   d. Disseminate media publicity. This would have to be limited and mainly in the form of news releases describing the department's efforts to promote water conservation. Care would have to be excercised to avoid the inference that the product of any particular manufacturer is being promoted. Radio editorials through metropolitan outlets are a possibility, and also pre-pared material which could be broadcast in "free time" as public service announcements. Trade publications, interested in potable water suplies, and ecology magazines might use carefully prepared materials describing the New Jersey efforts in water conservation. Articles should be prepared for publication in such periodicals as NEW JERSEY OUTDOORS', EFFLUENTS, the New Jersey League of Municipalities publications', and PIPELINE, the official publication on the New Jersey Section A.W.W.A.
   e. Prepare a general brochure for general distribution to the public, if appropriate funds can be made available. The brochure, "ACustomer Handbook on Water Saving and Wastewater Reduction," published by the Washington Suburban Sanitary Commission, and the smaller brochure, "Water Conservation At Home," published by the American Water Works Association, contain excellent material and could be used as a guide, though the latter confines itself to water saving practices, rather than fixtures and devices.

COOPERATION BY INDIVIDUALS

We would like to count on the unstinted support of the individuals who are here today to help implement our water conservation program. Such a program would reduce the need for capital improvements currently needed, by both water purveyors and sewerage undertakings, to meet growing water demands. Water conservation has been successfully promoted elsewhere in the United States and for further guidance on what can be accomplished at a local level, it is suggested that you will refer to the excellent article wich appeared in the January 1976 issue of WILLING WATER which describes a program implemented by the East Bay Municipal Utility District, Oakland, California.

The final paragraph of that article is well worth repeating - "Water conservation in some form is here to stay - it's a fact of life today; tomorrow it must be a way of life."

New Jersey's Water Supply Needs and the Master Plan

William Whipple, Director, N.J. Water Resources
Research Institute
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The last speaker had a solution to save water because he's going to readjust the plumbing fixtures. Based on the bathing habits of my children, my suggestion to save water would be a large activated plunger with a rubber hand on it that would push them out of the shower at the end of ten minutes.

Of course, when I was a young man staying in England, I had to stay in very cheap lodgings; they only had one bathroom to serve about 15 bedrooms, and so the bathroom had a water conservation device in the form of a motto that was placed in large letters on the door. It said "The lease on this well watered spot is short, so haste and tarry not, for in a brief ten minutes more, the next will thunder at the door."

New Jersey has made various efforts to definitively solve its water supply problems. In the days of George Shanklin, whom many of you will remember, when people would accusingly say that New Jersey didn't have a water supply plan, George would always say, "Oh yes, we have," but nobody could ever find a copy of it. It existed mainly under his hat. I don't want to imply that there weren't some good ideas there, but there was no definite plan to refer to.

In 1955 there was a consultant study authorized for New Jersey which surveyed the water supply problems of the state. Its conclusion, generally, was that there was plenty of water, although it was, if you read the text carefully, sometimes it was at the wrong places and came at the wrong times. This stated conclusion led to a certain degree of complacency. Actually that study had a major deficiency in that it did not consider what water would have to be left in the streams. In other words, it proceeded from the concept of safe yield, without adequate provision for remaining flows, and so it was somewhat unjustifiably optimistic.

In 1960-61, the Corps of Engineers completed its comprehensive plan for the Delaware River Basin, a major undertaking. This plan considered flood control and many other things. It did include a regional water supply analysis and concluded that New Jersey was going to have major water needs that could not be satisfied without considerable storage. It recommended the construction and operation of the Tocks Island Reservoir to provide 300 million gallons a day of water supply for New Jersey. This additional water was necessary because New York State, with perhaps greater foresight and certainly greater political heft, had proceeded to lay hold of a great deal of the water supply of the upper Delaware Basin, and had installed its own reservoirs to make sure they got the water before it got down here. Meanwhile, New Jersey had recognized that its early report was not completely adequate and had proceeded with the construction of Round Valley and Spruce Run Reservoirs, which at least would store some of the excess water in the Raritan River Basin. Although these reservoirs were well-conceived, they have not been fully utilized, because the delivery plan was left to cooperative action between several municipalities, which never quite got together to build a delivery system under the terms of the act. If the big drought had lasted one more year, I think they would have done it. But it didn't, and we still have no fully adequate delivery systems, although movements are being made in that direction now.

The next major analysis was completed in 1973. This seven-year study of the water resources of the entire North Atlantic Region was funded by the federal government, participated in by several federal agencies, and had supposedly the full cooperation of the various states. In fact, state cooperation was largely nominal; and it was primarily a federal study. This report projected a very great expansion of water needs in New Jersey. I'll just quote the figures for Northern N.J. which, of course, is the center of the water supply difficulty. They estimated that the population, which was then 4,800,000, would grow to 6,700,000 by the year 2000, and that the public water supply requirements would grow a great deal more than proportionately. These requirements would grow from 500,000,000 gallons a day to 1,200,000,000 gallons a day, an increase of two and a half times. They made the assumption that the public water supply would have to increase faster than the population partly because more communities would have to use public supply rather than privately owned wells, but also because they felt that self-supplied industry was going to find it unable to meet its own further requirements and would have to buy public water. It is now generally considered that the population estimates in that report were somewhat high, as the population trends in this state and in other states in the United States have very considerably dropped. We can no longer accept the requirements estimated in these studies as definitive, although they were, I think, competently made, with the assumptions that were in existence then. However, they certainly proved that we are going to need a great deal more water. We have since then had the decision not to proceed with Tocks Island Dam. Like Grant Walton, I will avoid giving my opinion as to the reasons of that decision. That project, while not perhaps dead, is certainly in a state of long-time suspended animation, and cannot be counted on for water supply in the immediate future or, in fact, in any future.

In 1975 the state, after several years of consideration in the matter, came to a definite decision to proceed with the preparation of a master plan for water supply for the state of N.J. and provided the money to do so, a big decision to make because this is a costly matter to initiate in a year of budgetary stringency. The decision having been made, a preliminary contract was awarded to a small engineering firm to outline the proposed scope of the plan. I am a senior advisor to the state for that plan along with Dr. Abel Wollman of Johns Hopkins. We are not actually preparing part of the plan, but rather analyzing and making recommendations. A consultant selection committee procedure was devised, bids were requested from a number of consulting firms and, under the procedures adopted, proposals were received from about 37 different firms and then the lengthy task of evaluating them and making a selection began. A selection was duly made last April, and the contract, I believe, may be signed today. As these dates will indicate things are not moving extremely rapidly. There have been some administrative problems in the state in connection with the letting of this contract that are extremely, I'll just say, regrettable. I won't say any more about it because, after all, I have friends in state government whom I don't want to offend. The consultants selected were in a consortium, headed by Havens and Emerson and including the ubiquitous firm of Parsons, Brinkerhoff, Quaid and Douglass, which seems to appear recently in most of the big things going on in water for the state of N.J., Water Resources Engineers, a California firm extremely skilled in water and water quality modeling, Geraghty and Miller, who have some of the best ground water people in the United States, and Westwater, Gaston and Dunkor, a small but enterprising group which will be doing the institutional aspects of the study. So it's a very complex consortium of consultants. The administration of this contract by the state DEP is under the capable hands of Dirk Hoffman, who has been an energetic member of the state administration for some time, assisted by Joe Miri, a political science Ph.D. from Rutgers. It is a new development to have a political scientist as a staff member of the state DEP.

Now what are the consultants going to do? The first of nine required tasks is to prepare what is called a data base. This "data base" actually includes some of the most important things that have to be done for the project. First, they have to delineate areas and define the water supply infrastructure. The use of this term rather amuses me. It's a military term taken over now for other uses. As used here, the infrastructure means the supply and marketing arrangements of the different firms which supply water in different parts of the state. Historic records of diversions and of water use have to be compiled. Next there are two major tasks that are extremely important. One is to define the design drought. Now, that sounds like a meteorological and statistical job, and it is; but it's also extremely important from a policy viewpoint. The reason is that if you are going to define safe yield on the basis of a drought which has a recurrence interval like that of the 1960-66 drought, generally estimated at once in 500 years, you won't have nearly as much water to count on as though you chose design drought of more frequent occurence. Moreover, selection is further complicated because that drought did not impact equally on all parts of the state. It was much more severe in the northern part of the state than it was in the southern part of the state, and there were other inequalities, so that it cannot be accepted automatically that any one drought is equally applicable in all areas. It is a complicated matter, and people have been worried about it for some time, because of the implications of what you mean by safe yield, which will be defined by the design drought. Another thing that I think may be equally important, since it really controls much of what can be done, is the definition of minimum stream flows. Let us consider the Raritan River. The water supply people have a tendency to consider the flows in the Raritan River in dry periods as though they could all be used. On the other hand, the water quality people are assuming, in making the Section 208 plans, that the Raritan River will continue to flow and disperse the pollution that comes in from various sources, to dilute it, and to carry it out into the bay. Now, the recognition of the realities of this situation has been clouded by a slogan, a very bad slogan, although it was very popular for a while, and that is "Dilution is no solution to pollution." Although it sounds so good, it actually is very misleading. Whereas it is perfectly true that you can't solve gross pollution problems by merely adding more water into the stream, it is equally true that if you have a stream that is flowing like the Raritan today and you remove half of the low waters from that stream, you have a much worse pollution situation, than you had planned. So the size of the stream, the quantity of water flowing in it, is a very important determinant of what the water quality will be, given the population and industry that line its banks. Therefore, the definition of what these minimum flows should be, on which planning is to be based, is one of the very important jobs which is hidden under the title: data base.

The second title is "needs assessment." Now, you get into a good many semantics problems in defining needs for water. The consulting firm very properly points out that when you define requirements as a single figure, as in the figures I just gave you of water supply need going from 5 hundred to 1 thousand 2 hundred m.g.d. those figures are ambiguous, because of the question - what is a requirement? For example, requirements might be based on 100 gallons/ day/ person which is a common planning figure for domestic use, but on the other hand, when the American forces in World War II were fighting in the Libyan desert, for awhile, the Second Corps was getting along on two quarts of water per person per day. And people can for a while exist on two quarts of water per person per day, if you assume that you are only going to wash your self once a day, using a little water in a helmet and drink the rest of it. Of course, for the luxury of an all-over shower, that has to wait until you get back when the battle is over. The question of needs assessment has to be answered, but it has to be answered in terms of relative needs, not considering these figures called requirements as being absolute. The consultants will have to consider what the water supply demands are in the different areas, given population and land use, and the relationship of the needs of these areas to water supply availability and cost. The water supply requirements estimate will be on a modern basis that considers requirements economically as a series of curves depending on the urgency of demand, rather than a single curve.

The third of the major tasks is water supply development. This is the structural planning picture, the determination of the planning alternatives available in the different areas, including ground water as well as surface water, and including considerations of conjunctive management of ground and surface in one system, which is not always done. Essentially, under this task they'll have to consider the various possibilities of storage, of withdrawal of water that's not otherwise used, such things as the possibility of scooping up flood waters from some of these streams and storing it for future use, and in general, where can the water be obtained at what price? Now, when you get into these questions of course, New Jersey has a great deal of groundwater, and some people are very fond of saying that there are so many billion gallons of ground water underneath the pine barrens or other areas. It's true the water is there, but the question is not the total amount but how much can be withdrawn every year without causing trouble? And what kind of trouble? What are the full consequences of taking out groundwater? If you drew down the ground water too much, many of the shrubs and pine trees might dry up and disappear. Of course they might not, but we're not sure. All the little streams would definitely dry up. If the ground water is withdrawn near the coast, what will happen? You will have saltwater intrusion. If you take too much groundwater near the Delaware Estuary, the polluted waters of the Delaware may enter the aquifer, and so on. Of course around here, close to New Brunswick, there are important saltwater and pollution problems related to groundwater. The question of how much groundwater can be abstracted in such areas is very difficult. Of course we also have all of the various storage possibilities large and small, and the complications that they entail including environmental impacts for each one and relocation and transportation impact for many.

The fourth task is more easily defined. It's the task of interconnections. When something happens like the sudden breakdown of the pumps in Trenton, which left Trenton water supply operations absolutely strapped, people were astounded to find out that there was no way that water could be pumped into Trenton from nearby systems, except, I think, for one very small line. The reserve capacity of nearby systems wasn't available, because the water companies hadn't been connected up. This is one of the penalties we pay for individual decentralized accomplishment of our water supply tasks by various water companies. The state has to make some kind of arrangement to satisfy the conditions of an interconnection and make it economically viable and fair to the interests of the different purveyors, including both public and private. We must remember that N.J. has large private purveyors, particularly the Elizabethtown water company. There are very few states in the union that have such large and, I must say, such efficiently run private companies as we have here; but they are not all large and they are not all efficient; and certainly they are not all adequately interconnected. An interconnection plan is an essential part of any sensible scheme to maximize the use of water supply for the state as a whole.

Five, we will have contingency plans. What do you do if the well runs dry? This is closely related to the interconnection problem. During the last major drought, there were considerations of draining water from lake Hopatcong and a variety of other proposals that might be resorted to in an emergency; and in other parts of the country they've had perhaps worse things than that. The great drought in the Southwest ending in 1957 was the greatest on record in that area; and people in Texas were finding flows in their streams lower than they had ever been before. The city of Dallas laid a flexible pipeline overland and pumped water down, I guess, 120 miles from the Red River, to the north. The only trouble was that that river carries 3,000 tons of salt a day, and also other minerals. The water is very poor quality. When people watered their gardens, it killed azaleas and other sensitive shrubs, but what it did to the insides of the people is not recorded. But this was a rushed contingency plan. If you have more time to think about contingency plans, they can be improved. So number five is preparation of contingency plans for the state.

Task number six will be to outline conservation plans. Something like the things that we're talking about today, that may be practicable for our saving of water.

The last three tasks relate to management alternatives. This is not to be just an engineering study because the problems of the state are not just engineering problems. Number seven is called water resource management, and this is to evaluate what can be done at basin level, which will be illustrated by five basin plans. This doesn't necessarily say that this water will be managed by basin but certainly the evaluation of the optimim basin-wide use of the resources is a sensible thing; and it may be that basin-wide management may be required. In England and in France, for example, every basin in the country, as designated, has a special body created to take care of water supply and water quality and water-based recreation matters for that basin. If we had such a law in this country, you'd have a Raritan Basin Authority which would handle water supply and water quality for the Raritan Basin. You'd have probably something like the same thing for the Passaic. We have no such bodies and it's not at all clear that they'll be recommended in this study, but at least the problems of management will be considered on a basin-wide basis.

Number eight will be regulatory system-management. What can be done about administrative activities and revenues, including possible water fees to make the system self-supporting? Number nine will be state water utility operations and activities, essentially a blueprint as to how the state might most economically and efficiently conduct its own operations.

Now, this whole master plan will be, I think, a great step forward. It means that the state has mobilized resources, they've got competent consultants, and they will be moving towards indicating solutions to some of these major problems. I might say, also, that there are considerations of public participation, very large provisions for public participation, so that as this goes forward you can expect meetings of various types, contacts at various levels to make sure that different municipalities, the water users, and the water companies get into the act and have a chance to make sure that their needs are properly considered.

Among the most serious basic problems that have to be dealt with in this planning process are as follows. One, is the question of the periodicity of droughts. We are accustomed to thinking in terms of water as always being there but the drought of the 60's was enough of a warning to us in this part of the country that it may not be, that you do have recurring droughts. This was the greatest drought that we know of for certain parts of the Northeast. In the Southwest, I've mentioned the great drought of the 60s, which lasted for 6 years and was ended by a year of floods that were even more damaging than the drought. The great western plains had a 7-year drought going from 1931 to 1936; and it was the greatest drought that had ever existed out there since the time the land had been settled. However, when you make other studies, you find that other droughts had lasted for a longer time. There was a drought for 11 years in Massachusetts at one time. It didn't cause as much excitement because Massachusetts generally has a lot of water. I define drought there as a prolonged period in which the flow each year is less than the long time average. Now, when you go further back, what is the maximum length of drought that you could expect? Well, I don't want to frighten anybody; but tree ring records in Southern California indicate that somewhere around 700 years ago there was a drought that lasted 43 years. Of course, there wasn't anybody around except a few Indians to be affected by this; and I'm not suggesting that this is about to happen here. But the fact is, unusual meterological occurrences happen sporadically, and there is certainly no reason to conclude that the drought of the 60s is the most severe drought that could occur; nor should we expect that it would reoccur with any predictable interval. Drought will probably occur in some quite different form and location when it hits next time in New Jersey. It might be much more severe and last only 2 years. It might be milder and last 11 years. It might hit the southern part of the state rather than the northern. We have no way of knowing how the situation will develop.

Now, the other water supply problem besides the droughts is a question of preserving water quality. At this point, I have to get in one plug for my own activities. The Water Resources Research Institute here has been working on water quality and environmental impacts as its major activity for the last 11 years; and is heavily involved in water quality planning. I'm particularly conscious of this matter, because I can see what's happening on the pollution front. We have economic growth occurring. The upper Passaic is, I think, the most obvious basin, where very rapid population growth is occurring, in the neighborhood of 5 percent annually, and the increased industry and population up there is greatly increasing the pollution that occurs in the rivers. Now, of course, as you all know, the EPA and the state DEP have got very vigorous programs of pollution control. They are directed, however, at the waste treatment plants and the effluents that those treatment plants put in the streams. They are requiring more elaborate forms of treatment and it's making a good deal of difference. However, there are many unrecorded and nonpoint sources, and these are increasing the pollution in the streams at the same time that the treatment plants are reducing it. The basic water quality is in many cases only barely holding its own. We're not making the progress that we should. As population increases, as urban centers, shopping centers, multiple family housing, added automobile traffic, and all kinds of industry and commerce grow, there are inevitably increased pollution loads of sediment, of BOD and of other pollutants. In our most recent studies we've found that there are petroleum hydrocarbons, coming off in urban run-off at rates 2,3, or 4 milligrams per liter. When such hydrocarbons get into a water supply plant they get chlorinated, and chlorinated hydrocarbons are bad news in anybody's book. We don't know the details of what's happening to these hydrocarbons yet, but we do know that chlorinated hydrocarbons include both toxics and carcinogenics. We know that the heavy metals are coming from these urbanized areas: lead and zinc mostly, copper, and occasionally significant loads of nickel or cadmium. These all mean problems.

Also for our preservation of the water quality in the streams we must have sufficient water to continue to carry off the wastes. The Raritan river has been improving in water quality for the last four or five years very largely from the fact that the increased flows due to Spruce Run Reservoir have not been fully used, and this additional water has correspondingly improved the water quality. But that can't go on indefinitely. Water supply was what that reservoir was built for, and ultimately it will have to be used. Round Valley will also allow abstracting additional water from the river; so that the water quality plans for the Raritan River have to contemplate a reduction in the average flows that will be available for that purpose. There is insufficient coordination between the 208 Water Quality planning that is going on, and the water supply picture. It is apparent that water supply and water quality planning should be co-ordinated, but in point of fact, the institutional arrangements of the 208 planning on the 20A and the water supply planning on the state are so different that it is difficult to get them coordinated. The state plan has the better provisions for coordinating with water quality, because the section 208 plans do not really explicitly recognize the water supply problem at all.

The new safe drinking water act is coming into operation, effective next summer. It's going to place additional requirements on the water purveyors for testing their water and for keeping out pollutants, a long list of pollutants. Now, how are they going to do this? How are they going to treat these waters to remove these pollutants? Actually, water may be so polluted that it becomes economically not possible or not practical to treat. As this Safe Drinking Water Act comes into effect, people are going to have to give a lot more attention to the reconciliation of the water supply and water quality aspects. I think this is the problem that requires the most research and the most consideration, because most of the other problems we know how to solve, but this one I'm not sure we do.

Water Conservation With Water-Saving Devices

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Water conservation is fast becoming a way of life in many parts of the country. The "limitless resource" has become limited in places like Florida, California, Colorado, and even the humid Northeast. Industry is learning that it is cheaper to reduce wasteflow volumes and recycle water after treatment in order to meet new environmental regulations. The alternative to conservation seems to grow less and less attractive as water and sewer development costs rise and objections are raised to committing land to water development projects.

The effort to clean up the nation's waters will eventually lead to the expenditure of $18 billion under the provisions of the Water Act. Needless to say those $18 billion will do much less of the job in 1975 dollars than they could have done in 1972. This is far less than is now thought necessary to meet the Water Act's goals. These costs make apparent the fact that it will be impossible to sewer the entire country; consequently, on-lot sewage disposal is not a stop-gap measure but a permanent reality.

Energy conservation has been the topic of much discussion in recent years. Many programs to save energy have been proposed. In our programming we must not overlook the significant quantities of energy that are used in the heating of water for residential and commercial use. Next to home heating, hot water use is the next greatest consumer of residential energy. Conserving hot water has the potential to reduce energy use significantly.

Various methods can be used to accomplish water conservation objectives. New pricing schemes are being developed which will greatly aid the conservation effort, but the affluent will remain little affected. Universal metering will help but the initial costs of meter installation are high and reductions in use are often temporary. Public education programs have been effective during crisis periods, but people tend to slip rapidly back into their established water use patterns. Water-saving devices offer hope of providing an inexpensive and lasting approach to water conservation for all Americans rich and poor. This can be done without major disruptions in water use habits; consequently, it should be a more palatable approach to the American consumer.

In the final analysis water conservation will require a combination of all of the approaches that are being discussed at this conference. New pricing schemes, universal metering, and public education will speed the acceptance of water-saving devices; however, they need not necessarily precede or accompany a water conservation program using water conservation devices. With this background let us proceed to identify some water-saving devices for the benefit of those of you who are not familiar with them.

Water-Using Appliance

Automatic Washers -- Water consumption by automatic washers ranges from 35 to 70 gallons per wash load, the exact figure varying according to habits of the user and the type of washer. Washers with suds savers use less water by providing for the reuse of wash water for a second wash load.

Water savings may also be achieved by automatic washers that allow the amount of water used to be adjusted for load size, and by using front loading models. Baker[1] has reported that front loading washers use about 15 gallons less water than top loading types.

Automatic Dishwashers -- The automatic dishwasher has done much to relieve the housewife of this unpleasant mealtime chore; however, dishwashers use water extravagantly, between 13 and 19 gallons of water per day. If dishwashers are loaded to capacity for each use, worthwhile water savings can be obtained.

It should be noted that following the above procedures to save water also saves energy by limiting hot water use in automatic washers and dishwashers.

Water Heaters -- This is probably the most common water using appliance in the home. Increased attention is being paid to this appliance and associated hot water distribution lines with respect to potential savings of energy. Such things as improved efficiency, better insulation of the water tank and distribution pipes, shorter runs between the heater and fixtures, and improved hot and cold water mixing valves are being investigated.

Water-Saving Devices

Bricks and Plastic Bottles -- Bricks and other objects have been used to save water in flush toilets that are designed to use more water than is necessary for adequate flushing. The brick is placed in the toilet reservoir, and the water it displaces (a little over 1 quart) is saved every time the toilet is flushed. More than one brick may be used depending upon the reservoir's size and design. Another object that works better is a discarded plastic bottle filled with water. The bottle should be weighted with a small stone or other object to keep it from floating around in the reservoir. When the toilet is flushed the plastic bottle holds back the volume of water it contains. Unlike bricks, the plastic bottles do not cost anything, will not deteriorate in water, and will not break the toilet reservoir if accidentally dropped.

Plastic Dams - Toilet reservoir volume reducers are being manufactured by several companies. These devices dam off a portion of the reservoir and retain that water when the toilet is flushed. Problems have been encountered with these devices and unless adjusted properly inadequate flushing may result. However, substantial savings (Washington Suburban Sanitary Commission reports 18 to 20 percent savings in total home water use) can result from their use and they are relatively inexpensive. These devices have proven to be cost effective.

Improved Float Assemblies -- Float assemblies of improved design are now available at most hardware stores. These are easily installed in most conventional water closets and sell for about five dollars. Water savings are achieved using these devices by adjusting them to maintain a lower water level in the toilet reservoir and by improved leak detection features.

Dual Flush Cycle Modifications -- A number of devices have been patented that can be incorporated into existing toilets to give them a dual flushing capability - one cycle for solids and one for liquids. The objective of these devices is to reduce the amount of water used to flush away liquid wastes. Tests of these devices indicate significant water savings can be obtained from their use. These devices were termed cost effective by an Environmental Protection Agency [2] study.

Faucet Aerators-- Faucet aerators are already in wide use. Faucets with aerators provide an even flow and reduce splashing. By mixing water with air they reduce the amount of water flowing from a faucet. Faucet aerators are easy to install and quite inexpensive, and will more than pay for themselves in a short time.

Spray Taps-- Spray taps are a later development in water-saving devices. These taps are actually mini-showers designed for use in lavatory sinks and wash basins. Water is sprayed from the tap rather than issuing forth in a single stream as is the case with conventional faucets. The spray allows for faster washing and rinsing with less water use as a consequence. When such devices are combined with thermostatic mixing valves, water savings of up to 90 percent are claimed by the manufacturer.

Flow Control Devices -- These are used to limit the rate of flow from shower heads and faucets. These devices are usually nothing more than orifice restrictors that fit into the supply lines for faucets or showers. Flow is usually limited to 3 gallons per minute for showers. Normal flow from showers is 4 gallons per minute and up. Water savings of up to 50 to 70 percent are claimed for flow-limited shower heads and up to 50 percent for faucets.

Substantial savings can be achieved with flow-limiting devices in shower heads. Shower heads with built in flow controls are also available from several companies. A very inexpensive plastic flow restrictor is now available that fits inside the shower arm. Although the literature is conflicting on the actual amounts of savings, these devices were termed cost effective by Environmental Protection Agency studies.

Water-Saving Toilets -- Water-saving toilets are now being manufactured in this country. They are required by local plumbing codes in some areas. The principal feature of this type of toilet is a smaller water reservoir than that of a conventional toilet. These toilets use only 3½ gallons per flush as compared to 5 or 6 gallons for a standard toilet. This amounts to a savings of 30 percent in toilet water usage. Water-saving toilets are operated the same way as conventional toilets and are little different in appearance. These toilets are economical in new construction or as replacements for unworkable toilets.

Two-Cycle Toilets -- An improved toilet now in use in Britain is the two-cycle wash down water closet. The difference between this toilet and our toilet is that there are two separate flush cycles, one for urine and one for feces. Also the flushing action is of the wash down type while U.S. toilets are of the vortex siphon type. Less water is required for wash down units, but the toilet bowl requires more frequent cleaning. The solid waste flush cycle uses 2.5 gallons per flush while the liquid waste cycle uses only 1.25 gallons per flush. The flush cycles are initiated by a short pull on the flush handle for the smaller amount of water, and a longer, more persistant pull for the larger amount of water. When these figures are compared to the 5 to 6 gallons of water used to flush our standard toilets, the tremendous potential for water savings is obvious. Unfortunately, these toilets are not as yet being manufactured in the United States.

By combining several of the water saving devices that have been discussed a greater total saving of water can be obtained. For instance, if a volume reducer, an internal flow control device, and two faucet aerators are installed in a single four-member family home, the cost estimates would be as in the following table.

Sewer, water, and power rates have been on the rise and in many areas exceed the values used to compute this table. A daily savings of 24 gallons for showers with flow controls was used. This is really only a guess. It is about the same as that reported in the Washington Suburban Sanitary Commission Cabin John Study [3] but much greater than that reported in a recent Environmental Protection Agency [2] study. It should also be pointed out that these savings are based on a daily home water usage of 255 gallons.

Material cost:	1 plastic dam at $3.68 1 flow control at $.90 2 aerators at $1.50	$ 7.58
Labor cost		0
Total installation cost		$ 7.58
Expected life (15 years) (21 years for plastic dam)		
Cost per year		$ 2.00
Maintenance and power cost per year		0
Cost of water saved per year (at .42 cents/1000 gal)		$11.65
Cost of power saved per year (at 2.5 cents/kwh for shower only)		$23.37
Cost of sewage saved per year (at .50 cents/1000 gal)		$ 7.30
Total savings per year		$42.32
Net savings per year		$40.32

Water saved per day - 66 gallons

Recycling Wastewater -- Recent studies have shown that wastewater from sink, bathtub, and laundry drains is satisfactory for reuse in toilet flushing without treatment other than simple filtering and disinfection. Wastewater from these drains can be stored in a tank connected to the toilet reservoir. In this manner most of the water usually required for toilet flushing can be saved. A system of this type has been in operation at the Grand Canyon National Park for many years. Staining agents and bacteria may pose problems with this type of reuse. Color and murkiness will normally also be present to a degree. This may be objectionable to some people. Use of recycled water to flush toilets is already being tried in some water-short areas of the country. A recent Environmental Protection Agency demonstration project concluded that recycle systems may be cost effective where homes are suffering from malfunctioning septic tank systems.

Vacuum Systems -- In this system a vacuum pump removes wastes from the toilet and transports them to a holding tank from which they are fed into the sewer line. Such a system uses a mere 10 percent of the water required by the standard flush toilet. This type of system is too expensive for installation in individual homes, but it appears to be attractive where many toilets can be joined to a central vacuum system as in hotels or housing developments.

Pressure Reducing Valves -- It appears that pressure reducing valves, when installed at the home water supply inlet can effect considerable water savings in high pressure service areas. The Washington Suburban Sanitary Commission has altered their plumbing code to require pressure reducing valves wherever water pressures exceed 60 psi. The valves must maintain pressure in the 50 to 60 psi range.

Instantaneous Tempered Water Devices-- A device is currently on the market that offers a push button selection of flow rates and water temperature at the tap. Another less elaborate and less expensive device is being developed that will premix hot and cold water and deliver tempered water instantaneously at the fixture. These devices save water that otherwise would have been wasted while adjusting hot and cold water to obtain the preferred temperature.

Lavatory-Toilet Combinations -- This device allows for the direct reuse of lavatory wash waters to flush the toilet by combining the lavatory sink and toilet into one unit. Wash waters are collected in a standard toilet reservoir where they are used for toilet flushings. These devices are being manufactured by a Japanese firm.

Air Assisted Toilets -- A toilet that uses .5 gallon of water per flush is being sold in the U.S. It uses compressed air to assist the flushing action and can be retrofitted thater easily into existing dwellings. This toilet has been used successfully on Amtrak trains and at several West Coast ski resorts.

Other Innovations -- Air assisted showers using .5 gpm of water are now being marketed as are various waterless toilets. Types of waterless toilets include gas and electric incinerators, composting toilets and mineral oil recycling systems. A new Japanese toilet uses a cup of water per flush. This toilet employs a detergent to wet the sides of the bowl to facilitate the passage of solids. This toilet is currently being tested by the National Bureau of Standards. All of these devices are now commercially available in the United States.

This is a brief look at some of the types of water-saving devices currently available. New devices are constantly coming on the market. Major plumbing-ware manufacturers will also continue to introduce new water-saving product lines. With the spiralling costs of water, waste treatment, and energy there will probably be adequate incentive for consumer acceptance of water-saving devices; however, the rate of this acceptance will depend upon the degree of public awareness of these devices and their availability in the market place.

In April 1975 a state of the art conference on water-saving device technology was held at The Pennsylvania State University. Questions about the impact of water-saving devices on water consumption, and the cost effectiveness of various water-saving devices and water conservation programs were addressed by the various speakers. It was apparent from this conference and subsequent ones in North Carolina and California that there is a general lack of experience with water-saving devices and their impact on water consumption. However, these conferences have given valuable insight into the potential of water conservation programs using water-saving devices.

Water Consumption Reduction

Results presented to date on the amount of water that can be saved by using various devices have been mixed. The largest scale demonstration has been that conducted by the Washington Suburban Sanitary Commission[4]. Their results are indicative of the problems in obtaining a meaningful reading of the effectiveness of the various devices. It does seem from the WSSC data that in resident owned dwellings where utility bills are paid separately by the resident, significant water use reductions can be obtained. This was the case in the Cabin John Project. However, in the various apartment complexes tested, where landlord-tennant situations prevailed, the retrofitted water-saving devices did not seem to be effective in reducing water use.

Wasteflow Reduction

Most authors have tended to minimize the impact of water-saving devices on wasteflow volumes. When one considers the proportion of wastes treated at the sewage treatment plant attributable to household wasteflows the reasons for this are clear. With significant inputs of infiltration-inflow and industrial wastes the maximum theoretical reductions in sewage flow reaching the plant are about 7 percent. However, Cole has indicated that a substantial extension of the hydraulic life of a sewage treatment plant can be obtained if water-saving toilets are required in all new housing following that plant's construction.

In the case of on-lot sewage disposal systems the potential reductions for various water-saving devices are much higher. Bennett[6] reports that up to a 40 percent reduction in sewage flows reaching on-lot disposal systems is possible with current water-saving device technology. Such reductions have a tremendous potential impact on the sizing of such treatment systems and may also permit increased acceptability of marginally permeable soils for septic tank drainfields.

In a recent EPA demonstration project wastewater recycle systems were installed in three homes with septic tank systems. In two of the three homes, normally experienced septic tank problems were not evident during the testing period. These tests indicated a 26 percent reduction in sewage flows using this device.

Energy Consumption Reductions

There is practically no reliable data available on the impact that water-saving devices will have on home energy consumption. A comprehensive treatment of the potentials for energy conservation arising from reductions in residential hot water use has been presented by Muller of the Federal Energy Administration. He indicates a wide variety of options for reducing hot water use, and estimates that if all these measures were fully adopted a daily savings of 560,000 barrels of oil could be achieved. The savings of energy accruing from the use of water-saving devices can be quite significant and may alone justify their installation.

Effects on Sewage Treatment and Collection

The effect of water-saving devices on conventional sewage treatment and collection systems is not expected to be very significant. However, problems could develop in collection lines that service a population of fewer than 500 persons. In such cases conventional design velocities may not be adequate for solids removal, resulting in blockages, odor problems, and excessive pipe corrosion. The effects on sewage treatment should largely be confined to small increases in detention times and waste concentrations, which would be beneficial. Where there is a significant infiltration-inflow problem it is unlikely that these effects will be noticeable. In developments where a widespread application of water-saving toilets is expected, house connections, laterals, and submains should be evaluated to insure that solids transport will be adequate.

Cost Effectiveness of Water-Saving Devices

Recent Environmental Protection Agency studies (Chan, Schaeffer, 8, 9) indicate that various water-saving devices are cost effective. Specifically mentioned for retrofit operations are shower flow controls, toilet inserts and dual cycle modifications for toilets. Water-saving toilets appear to be cost effective in new construction. In addition broad based programs involving the free distribution of inexpensive water-saving devices are thought to be economically justified. There also appears to be some evidence that bath and laundry water recycle systems may be cost effective where installation is made in a home that is experiencing periodic on-site disposal system malfunctions.

Availability of Water-Saving Devices

A severe constraint to widespread adoption of various water-saving devices has been their general lack of availability. These devices are not usually carried as stock items in most hardware and plumbing supply stores. Apparently the demand for the items has not warranted their being routinely stocked, and many of the newer devices are as yet little known in the plumbing trade. In 1974 an informal survey of the State College, Pa., area showed that only two of eight area plumbing supply distributors surveyed carried shower flow controls and none of the eight had toilet insert devices. Faucet aerators and various kinds of improved float assemblies like the one shown previously are generally available. Some items such as the plastic flow control valve shown earlier are only distributed by one company. Some local plumbing supply houses were still unaware that manufacturers of the product lines they carried were marketing water-saving toilets and these toilets were only available on order when available at all. Greater demand for these products created by increased public awareness is necessary before their availability improves. As production increases the costs of some of the devices, especially water-saving toilets, should be lowered.

Implementing Water Conservation Programs

The first step in implementing a water conservation program is to make a list of the available alternatives. Such a list might include some or all of the following:

1) Leak surveys
2) Water conservation in the water treatment plant
3) Pricing mechanisms
4) Metering
5) Consumer education
6) Industrial water conservation programs
7) Institutional and commercial conservation
8) Voluntary water-saving device installation
9) Mandatory water-saving device installation
10) Various combinations of the above

The alternatives or combinations of alternatives that are chosen will depend on the local situation. However, some observations about the various alternatives might be helpful. In any conservation program it is always good public relations for the sponsoring agency to make sure that it is doing all that it can to comply with its policies before it asks the public to do so. Leak surveys and water treatment plant conservation measures are a must.

Once these programs are underway a concerted public relations-consumer education program should be undertaken to make people aware of the need for conservation and enlist their support. This need not be prohibitively expensive to be effective. The Washington Suburban Sanitary Commission's experience is an excellent example of this type of public relations effort, and it is being used as a model by an increasing number of large West Coast utilities. The WSSC used poster contests, buttons, bumper stickers, mass media programming, logos on stationery, free water-saving kits, and many other methods to accomplish this task. When the public is convinced that a sincere effort to conserve water is underway they may be much more receptive to metering and pricing programs or code changes requiring water-saving devices. When public relations value is considered, the free distribution of inexpensive water-saving kits, such as the WSSC's, may be a very cost effective approach.

The next phase of a water conservation program is more difficult to decide upon. The success of the remaining alternatives may be directly tied to whether or not a system is metered. The increasing block rate pricing scheme cannot be applied unless use is measured. Some incentive for water-saving devices may be lacking if use is not measured, but unlike pricing schemes the use of water-saving devices is not completely tied to the presence of water meters. Voluntary or mandatory water-saving device programs can be implemented in any water supply system. Flat-rate customers can be offered a formula reduction in their rates for each type of water saving device installed. For example, if a water-saving toilet reduces household water use by 13 percent then a water consumer who installs water-saving toilets would be entitled to a similar percentage credit on his flat-rate water bills. In the case of water-saving toilets and some toilet modifications there may already be enough information to develop such formulas. Water-saving devices are much more immune to the overuse of water by the more affluent than are metering and pricing schemes. Water use reductions resulting from education programs alone are often temporary unless backed up with water-saving device programs. A New York report [10] estimated the installed costs of water meters at $120 each. Water-saving devices that are designed for retrofit operations could be installed in a home at a fraction of this cost, and a water-saving toilet could be added to this at a cost comparable to a water meter.

The California Department of Water Resources in a May 1976 publication on water conservation [11] made the following recommendations and policy statements on the use of water-saving devices:

1. In all new construction the following be required, either through state legislation or local building code changes:
   - -- low-flow toilets (state legislation enacted in 1976).
   - -- low-flow faucets
   - -- low-flow showers
   - -- pressure reducing valves where line pressure is above 50 psi
   - -- insulated hot water lines;
2. Local agencies encourage the following to be installed in existing housing, through education programs and by providing the water-saving devices free or at cost:
   - -- weighted plastic bottles, water dams, or other devices in toilet reservoirs to reduce flush-flows
   - -- low-flow showerheads or flow restrictors in the shower line
   - -- low-flow aerators on faucets
   - -- pressure reducing valves where line pressure is greater than 50 psi;
3. Only low-water-use clothes and dish washers be sold in the state;
4. Manufacturers of plumbing fixtures and water-using appliances be required to prominently display water use characteristics;
5. Local governments adopt ordinances that require phasing out of home self-regenerating water softeners and replacement with centrally regenerated units.

In addition, the Department of Water Resources recommended that:

1. Action recommended for the residential sector also be undertaken in the commercial and governmental sectors.
2. Water agencies use uniform, peak/seasonal, or increasing block rates in water pricing. Where possible, ad valorem taxes for water should be eliminated and sewage treatment costs included in the same billing system. Where appropriate, the lifeline rate concept should be included in the pricing system.
3. All water agencies institute effective delivery system leak detection programs.
4. All water agencies promote and assist in the detection and repair of household plumbing leaks.

The following policies were also outlined:

1. Assist local agencies in formulating necessary buildings and plumbing code changes to require water-saving devices.
2. In cooperation with local agencies, develop and submit specific recommendations to the International Association of Plumbing and Mechanical Officials on modifications to the Uniform Plumbing Code regarding requirements for water conservation considerations in the design of fixtures and in other aspects of plumbing.
3. Work with other state agencies to develop water conservation programs at state facilities.
4. Acquire the necessary expertise to provide technical assistance to local water agencies in their efforts to select effective pricing structures.
5. Examine the water systems throughout the state and recommend appropriate measures to ensure that actions are taken.

It would seem, then, that a community might consider the following as a list of steps to be taken in implementing a water conservation program.

1) Institute a leak survey and corrections program.
2) Practice water treatment plant water conservation where appropriate.
3) Initiate a public relations and education program.
4) If the water supply is metered, institute pricing schemes that make water more expensive as use increases.

5) If the supply is unmetered or after step 3 has been accomplished in metered systems, implement a water-saving device program.
6) Make contacts with industrial, institutional, and commercial users and assist them in formulating water conservation plans.

The following methods could be utilized to implement water-saving device programs at both the local and national level.

a) Voluntary acceptance through education and/ or the free distribution of devices (WSSC approach).
b) Voluntary retrofit of devices in existing dwellings with code requirements for devices in new construction (WSSC approach).
c) Mandatory for all customers served by the utility as a utility policy.
d) Mandatory as a requirement for government assistance in water supply development.
e) Mandatory as a requirement for government assistance in housing development.
g) Inclusion in government tax incentive packages for energy conservation programs.

Any or all of the preceding measures would serve to hasten progress in any water conservation effort.

Water-saving devices will reduce water use. Economists who have examined this method of water conservation tell us that most of the devices are cost effective. The question remains: how much water will water-saving devices save? Quantifying the water savings from various devices and combinations of devices under actual use conditions is the next necessary step in speeding the adoption of this relatively new and rapidly developing technology. Unfortunately, acquisition of the necessary data under actual use conditions is a long and costly job.

In closing, I would like to say that the realization that the natural resources of this country are limited has never been more apparent to the American people than it is today. Water is an abundant natural resource that has seldom been conserved. Demands for water resources are mounting while pollution continues to shrink the usable supply. Water resources development grows more expensive each day, as does the cost of treating the inevitable flow of wastes resulting from most water uses. Water use reduction with water-saving devices offers a major opportunity to alleviate some of these pressing resource management problems. Water conservation will be a definite part of America's future and water-saving devices have a definite place in this conservation effort.

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[continued]

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The Impact of Home Water-Saving Toilets on Wastewater Collection and Treatment

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INTRODUCTION

Domestic water consumption per capita in the U.S. has been increasing steadily from year to year. Recently people are realizing that the resource is exhaustible even in the water-rich areas of the country. Water resources were considered to be limitless and only needing development and management. However, studies report that it will be more economical to reduce water consumption than to develop new sources.

Water conservation will have an impact on water supply as well as on sewage. The objective here is to investigate the impact that the water saving toilet may have on domestic waste water, both in terms of concentration and flow rate. The literature currently has very little information that is useful to the sanitary engineer for evaluation of the effect of mass installation of these low flow toilet devices.

IMPACT OF THE WATER-SAVING TOILET

Several different types of water conserving toilets are commercially available. These have been reviewed by several authors (1,2,3,4,5) and could reduce the domestic waste flow by varying amounts depending on the water used per flush.

The calculations for the following comparisons were based on a solely domestic sewer system, with no infiltration, no commercial, and no industrial contributions, since the impact would be the greatest under these conditions.

At present the average domestic sewage contribution is 73 gpd/capita with the toilet representing approximately 41 percent (6,7). The average U.S. toilet contributes 5.25 gal./flush, so new low-flow toilets will reduce this 73 gpd contribution. We can then calculate the amount of sewage flow reduction which may be an advantage to the system; however, tied in with this reduction is a concern for adequate transport of solids

HOUSE CONNECTION

House connections are generally made from the street lateral on a 2 percent grade with 6-inch diameter pipe (8). Using the alignment chart for Manning's formula for pipe flow for an **n** value of .013 (9), full flow of 0.8 cfs and a velocity of 4.1 fps is found for this pipe. The flow in a house connection may frequently be due entirely to the toilet discharge, so that the worst condition for solids transport will be approached when this occurs. Table 1 reports the results for velocities and depths calculated in the house connections for an average toilet compared with a reduced water consumption toilet. The flush time was taken as 12 seconds for flush volumes of 5.25 gallons (average U.S.), 3.50 gallons. (Washington Suburban Sanitary Commission maximum), 2.00 gallons and 1.00 gallons. A flush time of 3 seconds was assumed for the 0.25 gallons flush which might be used with a compressed air assisted toilet. It was assumed that the discharge flow would be constant during this time and attenuation would not occur. The instantaneous flow peak will be compensated by attenuation.

The velocity and depth for partially full pipes were taken from the hydraulic-elements graph for circular sewers, with **n** variable with depth (9). The velocity at flow rates that might be generated in the connection with even a U.S. average flush toilet will be only a fraction of the full velocity. If the general rule is followed that a full sewer velocity of 2 fps is necessary to prevent solids deposition, with a miminum full velocity of as low as 1.5 fps acceptable, these partially full velocities exceed the 1.5 fps including the 2 gallons/flush (10). The toilet discharges down to and including 2 gallons/flush do not reduce the flow rate substantially and should pose no problem. However, the depth of flow drops substantially when less than 3.5 gallons/flush is used and may be a problem for solids transport. Four inch diameter house connections should be considered for houses fitted with low-flow toilets.

LATERALS, SUBMAINS, AND MAINS

It is standard practice to design sewer laterals and submains to carry at full capacity flow of 400 gallons per day per person and mains to carry at full capacity flows of 250 gallons per day per person (11). The high gallon per day design equivalent (100 gpd average per capita expected for a whole municipality) is used to allow for diurnal variation. The population is based on a prediction of approximately 20 years in the future and is usually based on saturation of the area. The assumption was made that industrial, commercial, and infiltration contributions would be zero, or the worst possible situation for solids deposition problems to occur and best as far as flow reduction is concerned.

Populations of 100, 500, 1000, and 10,000 were used to design sewers at minimum permissible Pennsylvania State requirements, and flows and velocities were calculated with actual expected domestic contributions, using standard as well as reduced flow toilets similar to those discussed under the heading "house connection." The sewer pipe and grade chosen were the minimum permissible sizes and grades to give a full sewer velocity of 2 fps. The minimum sewer size permissible in Pennsylvania is 8 inch regardless of flow. Table 2 shows the reduction in daily flow that would be

Table 1. House Connection Sewage Velocity As a Function of Toilet Discharge

Toilet Discharge (gal/flush)	Flush Time (sec)	Flow[1] cfs	Velocity[2] fps	Depth d/D
5.25	12	0.059	2.05	0.22
3.50	12	0.039	1.88	0.20
2.00	12	0.022	1.72	0.13
1.00	12	0.012	1.35	0.010
.25	3	0.013	1.35	0.10

[1] $Q_{full} = .8$ cfs

[2] $V_{full} = 4.1$

realized with water saving toilets. Table 3 shows the velocities that could be expected in a sewer of the minimum permissible design but with actual minimum flow. Until a flush discharge of 1.00 gallons or less is attained, there is essentially no effect on average daily velocity or peak hourly velocity (note that velocities are already poor with 100 population contribution). At volumes of 1.00 and .25 gallons/flush the change in velocity is larger but still is quite small. The depth at which these flows may occur is shown in Table 4. At 100 population equivalent flows the depths are quite low with any of the flush volumes and may be a problem. Depths with 500 population contribution and larger are reasonable for most any toilet contribution. Therefore it is probable that the impact will be negligible on the solids carrying capability of sewers of 500 and larger contribution and questionable below 3.5 gallons/flush for 100 population.

TREATMENT PROCESSES

Reduced water consumption toilets will have an effect on the amount and concentration of sewage to be treated. The effect on volume was shown previously in Table 2 and the effect on BOD is shown in Table 5.

Effects on preliminary treatment, clarification, and disinfection will be primarily due to reduced volume that will increase detention times or reduce surface loading within the unit process and as a result improve efficiency. Activated sludge treatment at first might be expected to be improved by both the increase in BOD strength as well as the increase in detention time. The greatest improvement from BOD strength increase might be found with true plug flow where the concentration advantage would play a role of increased Fickian diffusion. However, true plug flow seldom exists, and plants approach complete mix first-order kinetics (12,13). We find from analysis of the time concentration effects using the first order complete mix equations of Eckenfelder that soluble BOD removal is not changed significantly but the effluent BOD is really more dependent on the residual SS content -- i.e., the efficiency of the secondary clarification is extremely important.

New or existing plants would have longer useful lives if reduced volume consumption toilets were installed in all new residences. This is illustrated by a municipality which used a 13-year design period with a design population of 26,740 in 1983, Figure 1. If the plant were designed for 2.67 mgd for 1983 it should be enlarged to satisfy any population increase beyond that year. The population increase from 1970 to 1983 is 8,880 people and if these new people were all served by toilets consuming only 3.5 gallons/flush, the savings in sewage flow would be 102,000 gpd, assuming everything else remained proportionally the same. This sewage flow savings would lengthen the hydraulic service life of the plant by approximately 1½ years and quite possibly the overall service life by a similar amount.

Table 2. Sewage Flow Reduction as Function of Toilet Discharge

Toilet Discharge (Gal/flush)	Daily Flow gpd	% of Original Flow
5.25	73	0
3.50	62	84
2.00	55	75
1.00	49	67
.25	45	61

Table 3. Sewage Velocities in Laterals, Submains, and Mains as a Function of Toilet Discharge

	Velocity fps							
Population Contribution	100		500		1000		10,000	
	ADF	PHF	ADF	PHF	ADF	PHF	ADF	PHF
Toilet Discharge (gal/flush)	—	4:1	—	3:1	—	3:1	—	2:1
5.25	.7	1.0	1.0	1.4	1.2	1.8	1.3	1.7
3.50	.7	1.0	1.0	1.3	1.2	1.6	1.3	1.6
2.00	.7	.9	1.0	1.3	1.1	1.5	1.3	1.5
1.00	.6	.8	.9	1.2	1.1	1.5	1.2	1.5
.25	.6	.8	.9	1.2	1.1	1.4	1.1	1.4
V_{full}, FPS	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sewer size, inches	8	8	8	8	8	8	21	21
Slope, ft/ft	.0035	.0035	.0035	.0035	.0035	.0035	.0095	.0095

ADF = average daily flow

PHF = peak hourly flow

Table 4. Sewage Depth in Laterals, Submains, and Mains as a Function of Toilet Discharge

	d/D							
Population Contribution	100		500		1000		10,000	
Gal/Flush	ADF	PHF	ADF	PHF	ADF	PHF	ADF	PHF
		4:1		3:1		3:1		2:1
5.25	.10	.20	.23	.38	.31	.56	.38	.53
3.50	.10	.20	.22	.36	.29	.51	.34	.49
2.00	.09	.19	.20	.34	.27	.47	.33	.46
1.00	.07	.18	.20	.32	.27	.44	.31	.43
.25	.06	.17	.18	.31	.25	.41	.30	.40
d/D full	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sewer size, inches	8	8	8	8	8	8	21	21
Slope, ft/ft	.0035	.0035	.0035	.0035	.0035	.0035	.0095	.0095

ADF = average daily flow

PHF = peak hourly flow

Table 5. BOD Concentration as a Function of Toilet Discharge

Toilet Discharge (gal/flush)	BOD raw mg/l	BOD primary effluent * mg/l
5.25	200	130
3.50	238	155
2.00	267	174
1.00	300	194
.25	329	213

*Assume 35% BOD removed in primary clarifier.

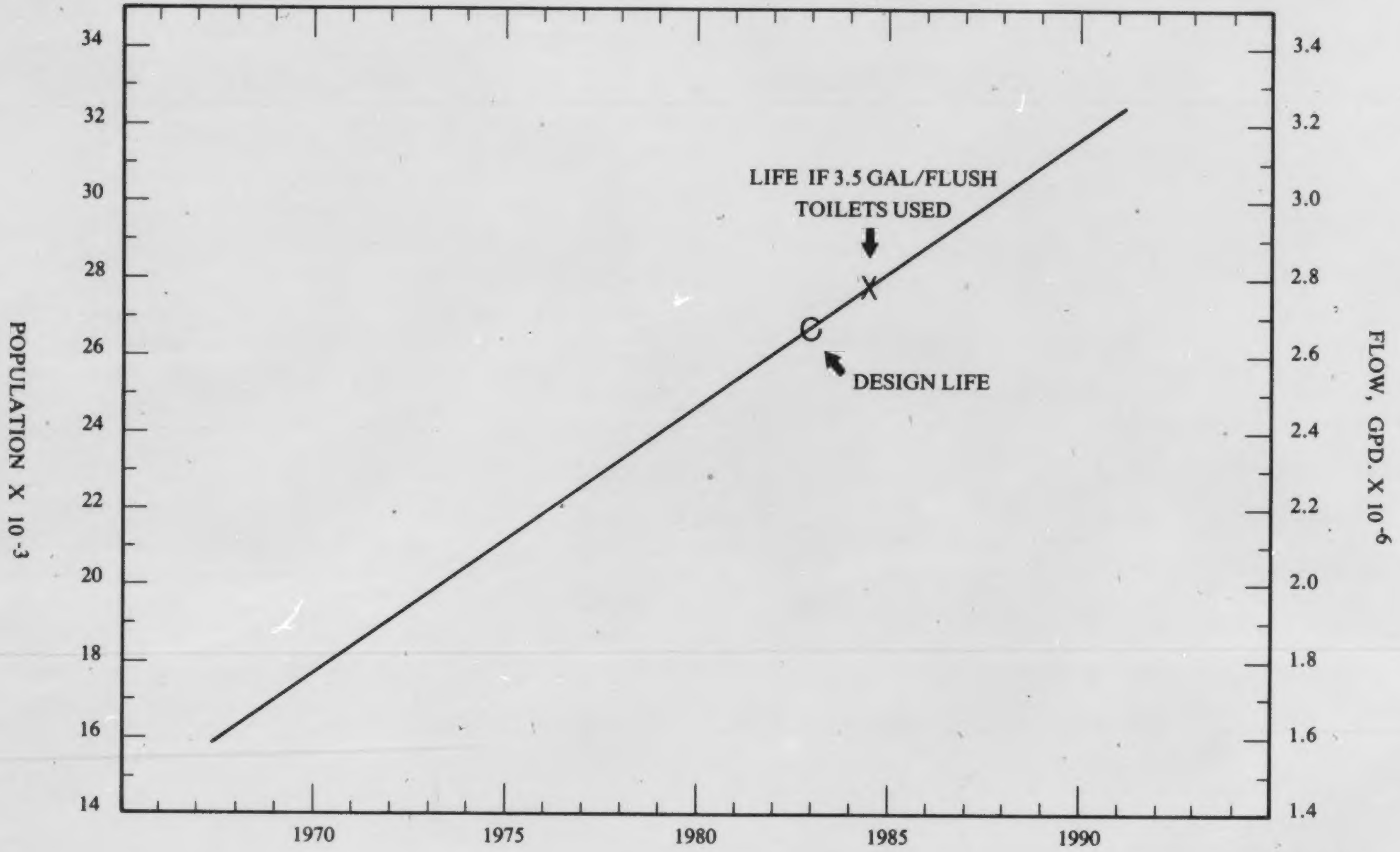

FIGURE 1. EFFECT OF REDUCED FLOW TOILETS ON USEFUL LIFE OF PLANTS.

SUMMARY AND CONCLUSIONS

Dwindling water resources and the expense of developing them combined with problems of treating the water and wastewater have made clear the need for water conservation. One way to conserve water and reduce sewage flow may be with the reduced flow toilet. An evaluation of this flow reduction on the sewer solids transport capacity, sewer flow handling capacity, and treatment processes capacity was necessary to evaluate the effect of the devices.

Calculations using minimum standards show that house connection and sewer velocities and depths are not reduced substantially below those that exist in a sewer with standard 5.25 gallons/flush toilets until the flush amount is reduced to 2.0 gallons or less. On sewers with 500 population and larger the velocities and depths are not substantially reduced for any of the predicted flush volumes. It should also be noted that infiltration and commercial contributions will tend to increase these velocities. Although the theory may predict no problems, sewer house connections, laterals, and submains should be evaluated in areas where reduced flow toilets will be installed to verify adequate solids transport.

The effect on the treatment plant appears to be primarily to increase the detention times or reduce the surface loading rates of unit processes and as a result increase their design life. Infiltration, however, may overshadow any benefit of toilet flow reduction and must be corrected before the toilet flow will have impact.

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The Potential for Energy Savings Through Reductions Through the Use of Flow Reducing Devices and Other Conservation Methods

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OUTLINE

- 1.0 **Summary**
- 1.1 **Introduction**
- 1.10 Magnitude of energy consumption for water heating.
- 1.11 Comparison with other energy uses.
- 1.12 Purpose of paper.
- 2.0 **Use Patterns**
- 2.1 Quantities required
- 2.2 Temperatures required.
- 2.3 Lack of reliable data.
- 3.0 **Water Heaters**
- 3.1 Principle of operation
- 3.2 Efficiencies
- 3.3 Electric versus gas.
- 3.4 How water heater efficiencies can be improved.
  - 3.40 Reduce losses through outer casing.
  - 3.400 Lower thermostat setting.
  - 3.401 Recovery of jacket heat loss for space heating.
  - 3.402 More or better insulation.
  - 3.403 Smaller tank size.
  - 3.404 Instantaneous heater.
  - 3.41 Improve efficiency with which heat content of fuel is transferred to the water when main burner is on:
  - 3.410 Improve combustion efficiency.
    - Reduce excess air.
    - Improve burner designs.
  - 3.411 Improve heat transfer by one or more of the following:
    - 3.4110 Additional surface inside heater.
      - (a) Longer internal flueway.
      - (b) Multiplicity of internal flueways.
      - (c) External flueway.
    - 3.4111 Economizer outside heater.
    - 3.4112 Improvement in overall coefficient of heat transfer from hot combustion gases to water by means of:
      - 3.4113 Extended Surfaces (fins).
      - 3.4114 Materials with high conductivity.
      - 3.4115 Increased length of time hot gas is in contact with flueway.
      - 3.4116 Higher gas velocity using forced or induced draft fan.
  - 3.42 Avoid loss of conditioned room air to support combustion when main burner is in.
    - 3.420 Outdoor installation.
    - 3.421 Sealed combustion.
  - 3.43 Minimize loss of conditioned room air up the flue when main burner is off.
    - 3.430 Reduce duration of standby periods.
      - 3.4300 Reduce size of main burner orifice.
    - 3.431 Take combustion air from outdoors:
      - 3.4310 Outdoor installation of water heater.
      - 3.4311 Sealed combustion.
    - 3.432 Reduce effective diameter of flue.
    - 3.433 Automatic flue gas damper.
      - 3.4330 Thermostatic type.
      - 3.4331 Electric type.
    - 3.434 Eliminate the flue entirely--discharge combustion gases indoors.
  - 3.44 Reduce backward flow of heat from tank and water into air passing up flueway during standby periods.
    - 3.441 Automatic flue gas damper.
    - 3.442 Reduce effective diameter of flue.
    - 3.443 One-way heat transfer.
  - 3.45 Reduce ignition energy requirement.
    - 3.451 Reduce size of pilot lights.
    - 3.452 Substitute electric ignition for pilot lights.
- 4.0 **Piping**
- 4.1 How piping heat losses can be reduced.
  - 4.10 Insulation
  - 4.11 Heat trap.
  - 4.12 Reduced pipe size.
  - 4.13 More direct runs and location of heater nearer outlets most frequently used.
  - 4.14 Lower heater thermostat setting.
  - 4.15 Two separate hot water distribution systems, one at 110°F., the other at 150°F.
  - 4.16 Combining hydronic space heating system with domestic hot water system.

- 4.17 Elimination of hot water piping by installing heater at point of use.

5.0 Showers

- 5.1 How hot water use for showers can be reduced.
  - 5.10 Shorter times in the shower.
  - 5.11 Flow restrictors.
  - 5.12 Aerated water.

6.0 Tubs

- 6.1 How hot water use in bath tubs can be reduced.
  - 6.10 Smaller size.
  - 6.11 Contoured to fit human body.
  - 6.12 Fabricated from material having a low specific heat.
  - 6.13 Insulate bottom and sides.
  - 6.14 Delayed draining.

7.0 Basins And Sinks

- 7.1 How hot water use at wash basins can be reduced.
  - 7.10 Smaller basins.
  - 7.11 Basins made of material having a low specific heat.
  - 7.12 Insulated basin walls.
  - 7.13 Flow restrictors.
  - 7.14 Aerators.
  - 7.15 Spray taps.
  - 7.16 Automatic closing faucets.

8.0 Indirect Energy Savings

- 8.1 At the water works.
- 8.2 At the sewage treatment plants.

9.0 Leaks

10.0 Laundry

- 10.1 How hot water use in laundry can be reduced by cold water laundering.
  - 10.10 Washing in warm or cold water instead of hot.
  - 10.11 Rinsing in cold water.
- 10.2 How energy consumption of clothes washers and dishwashers can be improved.

11.0 Heat Recovery

- 11.1 Recovery of heat now being wasted.
  - 11.10 Finned heat exchanger in attic.
  - 11.11 Basement tempering tank.
  - 11.12 Heat recovery from hot water drains.
  - 11.13 Water heater burning household trash and garbage.

12.0 Solar Water Heaters

- 12.1 Long-term economics.
- 12.2 First cost problem.

SUMMARY

It is not possible to make accurate estimates of the energy savings potential for water heating. Very little data are available on how Americans use heated water. Such information should be developed as soon as possible. Nevertheless, a cursory review of the various savings possibilities strongly suggests that water heating offers greater potential for energy savings that has been generally realized.

Our best estimate is that residential water heating accounts for an energy consumption of 1.1 million barrels per day (BPD) oil equivalent today, but this energy use could be cut sharply. There exist potential savings in excess of 500,000 BPD obtainable without adverse effect upon our health, comfort, or life style. The biggest energy savings potential is offered by the following measures:

Measures	**BPD Savings in Oil Equivalent**
(a) Replacement of existing water heaters over a period of years with more efficient heaters.	300,000
(b) Adoption of cold water laundering using improved detergents	100,000
(c) Use of flow restrictors in showers and basin faucets	100,000
(d) Miscellaneous other measures	60,000
Total	560,000

These numbers should be regarded as rough approximations.

Given adequate inducement, manufacturers are capable of carrying out the research and development program necessary to make the needed improved products available. The most difficult tasks will be to motivate homeowners to adopt the energy saving measures and to make available to these homeowners any necessary financial support. If these tasks could be accomplished, the bulk of the energy savings potential could be realized. But this is perhaps too much to expect. Surely, however, a saving of one-half the potential is actually achievable.

Solar water heaters have been omitted from the foregoing assessment. If installation of solar heaters were widely adopted, the energy savings potential would rise dramatically.

The Federal Energy Administration (FEA) and other government agencies will investigate America's patterns of heated water use, estimating the energy savings obtainable from various measures, evaluating any economic, social, and institutional problems involved, and taking appropriate action such as submitting to the Congress recommendations for legislation.

We welcome suggestions, particularly from people who are knowledgeable in the design of water-heating and water-using equipment.

INTRODUCTION

The United States has a serious energy problem. The supply of domestic petroleum and gas is not sufficient to satisfy our needs. Although the demand for oil and gas has continued to grow, domestic production has been falling. The growing deficiency has been replaced by increasing imports. In mid-March of this year, the combined crude and product imports reached 8,200,000 barrels per day (BPD) which exceeded for the first time total crude production of 8,000,000 BPD. The price of imported crude has soared, contributing to our inflation and recession. It has resulted in a massive outflow of dollars and, in effect, has resulted in a loss of jobs. More disturbing is the fact that, in an age when many relatively stable governments have fallen to revolutionaries, our economy has become dependent upon the continued availability of oil from relatively few foreign countries. (See Table I)

Under such circumstances, it is imperative that efforts be made to reduce energy demand.

Table 1 is an approximation of the nation's annual energy consumption analyzed by end use. Four points should be noted: (1) heating of water is the second largest energy use in the home; (2) the energy equivalent of 1.1 million BPD oil equivalent goes into residential water heating; (3) the energy equivalent of 240,000 BPD goes into commercial water heating; (4) residential and commercial water heating together account for about 4 percent of America's total energy consumption.

By way of comparison, we note that all automobiles account for 12 percent of our total energy use. And, while the fuel consumption of autos has received a great deal of attention from the government, public interest groups, the news media and manufacturers, the energy consumption associated with use of heated water has received little attention. Yet, it is in the nation's interest that the consumption of heated water be reduced.

It is the primary purpose of this report to set forth some of the many possible techniques for conserving heated water. Some of the measures suggested are practical, others are not. Implementation in some cases requires changes in building codes and/or new legislation.

A small amount of research has been done on the energy conservation opportunities connected with heated water. Hopefully, this paper will stimulate more groups to undertake research in the area. Where adequate information already exists, it is hoped that architects, engineers, government officials, and others concerned with water heating will take appropriate action to implement the measures discussed.

The secondary purpose of this paper is to set forth the approximate energy savings obtainable from the more promising energy conservation measures. Because basic data are lacking, the numbers arrived at are little better than first guesses.

Before proceeding, it is appropriate to comment briefly upon water use patterns and water consumption.

Water Usage Patterns. No systematic analysis of how water is used in a large sample of America's 70 million homes is known to this author. Table 1 shows one investigator's estimate of water uses in a typical home. Note that, except for the toilet, each involves some heated water.

It has been common practice to estimate water-heating fuel costs for a typical family on the assumption that 50 gallons of hot water are drawn from the heater each day or, if an automatic washer is used, 75 gallons per day. Of course, on any given day, hot water usage may be appreciably higher or lower.

Usage per family has been growing due to the more widespread use of automatic washers and dishwashers, and to the larger capacity of the newer appliances. The larger representation of teenagers in the general population may also be a factor. (Based upon my experience as a father of three, these young adults spend especially long periods in the shower.)

Temperature. The temperature of water supplied to the American home varies with the location, season of the year, and whether the water is drawn from wells or surface supplies. For the U.S. as a whole, the water temperature for much of the year may be less than 60°F. This is too cold for many household purposes. In most homes, water heaters are provided capable of raising the temperature of water to any desired point between 110° and 160°. Ordinarily the thermostat in the heater is set at the factory at 150°. Often plumbers, homeowners, or others will lower the setting of the thermostat on the heater about 10°.

There is some loss in temperature between the heater and the point of use due to heat transfer to the air from piping. Also, some heat is lost in sensible heating of the appliance. The temperature of heated water as used is approximately as follows:

Laundry (hot water wash)	130°
Dishwasher	140°
Shower and Bath	105°
Wash Basin	105°
Kitchen Sink	105°

Of course, the water for the last three named uses is in reality a blend of hot and cold water which is commonly referred to as "warm water. The term "heated" water will be used to identify any water warmer than the temperature at which it was supplied to the house.

[Table 1. on next page.]

Table 1.

Preliminary Estimate
1974 Annual Energy Consumption in the United States
By End Use *

Sector and End Use	**Consumption**		**Percent Of 1974 Total**
	tbtu	**BPD**	
Residential			
Space Heating	8,000	3,800,000	10.6
Water Heating	2,300	1,100,000	3.0
Cooking	700	320,000	.9
Clothes Drying	300	160,000	.4
Refrigeration	1,000	490,000	1.4
Air Conditioning	900	420,000	1.2
Lighting and Other	1,600	770,000	2.1
Residential TOTAL	15,000	7,100,000	20.0
Commercial			
Space Heating	5,000	2,400,000	6.5
Water Heating	700	240,000	1.0
Cooking	200	80,000	.2
Refrigeration	800	370,000	1.0
Air Conditioning	1,700	800,000	2.3
Feedstock	1,200	560,000	1.6
Lighting and Other	1,800	830,000	2.3
Commercial TOTAL	11,000	5,300,000	15.0
Industrial			
Process Steam	12,000	5,800,000	16.1
Electric Drive	6,200	2,900,000	8.1
Electrolytic Processes	800	390,000	1.1
Direct Heat	8,000	3,800,000	10.6
Feed Stock	3,000	1,100,000	4.7
Other		130,000	.4
Industrial TOTAL	31,000	14,000,000	41.0
Transportation			
Automobiles	9,200	4,300,000	12.1
Trucks	3,500	1,700,000	4.6
Aircraft	3,600	1,700,000	4.7
Railroads	500	250,000	.8
Busses	100	42,000	.1
Waterways	200	84,000	.2
Pipelines	200	84,000	.2
Other	1,400	640,000	1.8
Transportation TOTAL	19,000	8,800,000	24.0
National Total	**76,000**	35,000,000	100.0

* Totals do not add due to rounding

Table 2.

How Water Is Used By A Typical American Family Of Four

Use	Gallons Used Per Day
Dishwashing	15
Cooking, Drinking	12
Utility sink (washing hands, etc.)	5
Laundry	35
Bathing	80
Bathroom sink	8
Toilet	100
	255

WATER HEATERS

In most of America's 70 million occupied housing units, water is heated in a central water heater. Energy generally is supplied to the heater as gas, oil, or electricity. Census data revealed the following fuel-type breakdown in 1970:

Fuel Type	Percent of Occupied Households
Electricity	25.4
Natural Gas	55.1
Liquified Petroleum Gas (LPG)	5.0
Fuel Oil	9.8
Other and None	4.7
	100.0

Most commonly, the heater in a residence is a direct-fired type similar to Figure 1 with vertical storage tank, insulation, gas burner, and automatic controls all combined in a single unit.

In some cases, indirect water heaters are employed wherein service water is heated in a heat exchanger which uses, as its heating medium, steam or hot water generated in a separate cast iron or steel boiler. This boiler, at the same time serves for space heating of the home itself. Occasionally, service water is heated by simply running it through a coil installed inside the home heating unit, but this is only practical when water is low in hardness.

The average energy required in 1972 was: (a) for gas water heaters, 108,781 Btu per day or 397 therms per year; (b) for oil fueled water heaters, 104,138 Btu per day and 250 watts hr. per day (275 gallons oil and 95 Kwh per year); (c) for electric water heaters, 60,000 Btu per day (6416 Kwh per year).

For electricity at 4 cents/Kwh, gas at 27 cents/therm, and oil at 40 cents/gallon, this equates to $107 per year for gas fueled water heaters; $114 per year for oil fueled water heaters; and $257 per year for electric water heaters.

The efficiency of today's conventional gas-fired and oil-fired water heaters is 75 percent in factory tests. In actual residential use, less than 50 percent of the energy in the fuel burned in the year shows up as sensible heat in the water delivered by the heater.

The factory test efficiency of an electric water heater approaches 100 percent, but, in actual use, less than 80 percent of the heat given up by the heating elements shows up in water delivered by the heater. Moreover, it should be noted that, when appropriate allowance is made for the losses associated with the generation of electricity at the power station, and electric transmission and distribution losses, only 24 percent of the energy in the fuel burned at the power generating station ends up as hot water leaving the water heater. This suggests that replacing electric hot water heaters with gas-fired or oil-fired heaters is highly desirable. However, much of the nation's electricity is generated from coal, hydro, and nuclear energy. From the viewpoint of becoming independent of foreign petroleum, abandonment of electric water heaters is counterproductive. Since the average life of the heater whether fired by oil, gas, or electricity is less than ten years, new more efficient replacement heaters could have a significant impact upon the nation's energy consumption within a very few years. The efficiency of water heaters can be improved.

Insulation. Much of the heat input of water heaters is lost by conductive heat loss through the walls of the tank as shown in Table 3.

The Rand Corporation reports that heat lost through insulation accounts for about 20 percent of the annual energy use for a typical electric unit and 35 percent for a typical fossil fuel unit.

Lower Water Heater Thermostat Settings. Most residential type water heaters have adjustable thermostats which allow selection of any desired water temperature between about 110° and 160°. If the temperature of the water in the water heater is dropped by lowering the thermostat setting, the heat losses from the heater to the air and in the flue (and from the hot water piping in the house) will fall. This contributes toward energy savings because the rate of heat loss through the walls of a hot water storage tank is proportional to the temperature difference between hot water and the surrounding air.

According to the Rand Corporation, if the air is 70°, an electric water heater with standard tank insulation will use about 9 percent less energy with its thermostat set at 110°F than at 140°F. (1) Under the same conditions, gas- or oil-fired water heaters will use 15 percent less fuel. Of course, if the water heater is installed in living space, the heat given off is not wasted but serves to provide space heating. Admittedly, in the summer this is not desirable.

The tanks of most electric water heaters are covered with two inches of fiberglass or mineral wool insulation. The insulation on gas-fired and oil-fired heaters is generally one inch. By increasing the insulation thickness on gas-fired and oil-fired heaters to four to seven inches, fuel savings of 21 percent to 35 percent are possible. Savings of 5 percent to 11 percent are possible for electric units by increasing insulation thickness to three to five inches. From the buyer's viewpoint, the higher purchase price for a heater with added insulation is economically justified as shown in Table 4.

Adding insulation to existing heaters may be economically justified also. However, if for an extended period there is no water withdrawal from a heavily insulated tank, the heat of the pilot light could conceivably cause the water to be overheated. It would be appropriate to verify that a control is provided to turn off the pilot burner in the event of excess temperatures and that, in addition, an operable pressure relief valve is provided. An insulation blanket is currently being marketed which fits around the water heater shell. In the case of a gas-fired water heater, the $20 cost will be recovered in three years. In the case of an electric water heater, the payout period is only one year.

Tank Size. The sizable standby losses through outer jacket and flueway which are associated with any water heater, means that the annual service efficiency is strongly dependent upon the amount of water used. For example, if an electric heater were used but one day a year, its efficiency would be almost zero, because the heat loss from the jacket throughout the year would have to be charged off against a very small useful output. Thus, a heater which is heavily used will operate at a higher efficiency for the year than one which is used less. This suggests another method for reducing energy consumption: simply select the smallest acceptable tank size for any given application.

When tank volume is reduced, however, occupants may find that there is an inadequate quantity of hot water available during peak demand periods.

The ultimate solution is to select an instantaneous heater which has no storage tank. This, however, would call for very high heat release rates; but that is not readily accomplished. In the case of electric heaters, it would require a larger current flow than is permitted by some codes. In the case of oil- or gas-fired equipment, it would perhaps produce more combustion products than could be carried away in existing flues unless, of course, an induced draft fan were installed. There is nothing to prevent installation of gas- or oil-fired instantaneous heaters in new construction.

It is interesting to note that in Europe water is heated by small, gas water heaters mounted at the point of consumption, i.e., at the kitchen sink or in the shower stall. Simply opening the faucet activates these locally mounted heaters. The products of combustion are discharged into the room, so there is no flue gas loss. There is no water storage tank and virtually no hot-water piping, so the loss of heat to the air is low. Water flow rates are modest, however. A careful comparison of the performance of these units with the central hot water heater used in the United States would be of considerable interest.

Hot Flue Gas Loss. The gases and air which pass up the flue represent the largest single loss for a gas- or oil-fired heater. It is desirable to reduce this loss without raising the cost of the heater excessively.

The efficiency of combustion can be improved through adoption of better burner designs and by operation with lower excess air ratio. This will insure that the gases leaving the combustion zone are at as high a temperature as possible with minimum unburned or incompletely burned fuel. It is then necessary to extract the maximum possible amount of heat from these hot gases as they pass up the flueway. More complete heat recovery can be accomplished through increasing the heat exchange surface.

This extra surface can be in the form of a second flueway or a longer flueway inside the tank or supplementary external flueway around the outside of the tank.

The incoming cold water could also be first passed through a heat exchanger called an economizer installed in the flue outlet.

The effectiveness of the heat exchange surface could be improved by providing fins on the gas side or by use of materials having a higher thermal conductivity.

One way of increasing the heat transfer rate in BTU per hr/ft/°F is to install a serpentine baffle in the flueway. The hot gases taking a longer path in passing up through the tube are in contact with the tube wall for a longer period and thus may give up more heat. However, regardless of the technique employed, if too much heat is removed, the temperature of the flue gases drops so low (and the density rises so much) that there will be insufficient draft to carry away the products of combustion. (2/) A forced or induced draft fan must then be installed, raising the capital and operating cost of the equipment.

If so much heat is extracted from the flue gas that its temperature falls below the dew point, steel and other ordinary materials will undergo excessive corrosion. This can only be corrected by using acid resistant materials.

Loss of Conditioned Air During Burns. When a gas- or oil-fired water heater is installed in living space (or draws its air from living space) the total energy consumption chargeable to the water heater will be greater than the BTU content of the fuel it burns. This is because of the energy which has previously been expended in heating that air at an efficiency of perhaps 50 percent in the space heating furnace. In summer, a similar loss occurs when air colled in an air-conditioner is drawn into the water heater. Loss of conditioned room air can be eliminated by installing the water heater out of doors, or it can be installed indoors in a sealed room or box with duct work provided to bring in combustion air from outdoors. The latter is referred to as "sealed combustion."

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[1] For safety reasons, it is important that the electric power to electric water heaters be cut off before an attempt is made to readjust the thermostat setting.

[2] A fan is beneficial in a number of other ways. It produces a higher gas velocity and, therefore, higher heat transfer rates. It permits a smaller flueway diameter which reduces standby losses. It makes possible better burner design for higher combustion efficiency. It is more readily adaptable to sealed combustion operation.

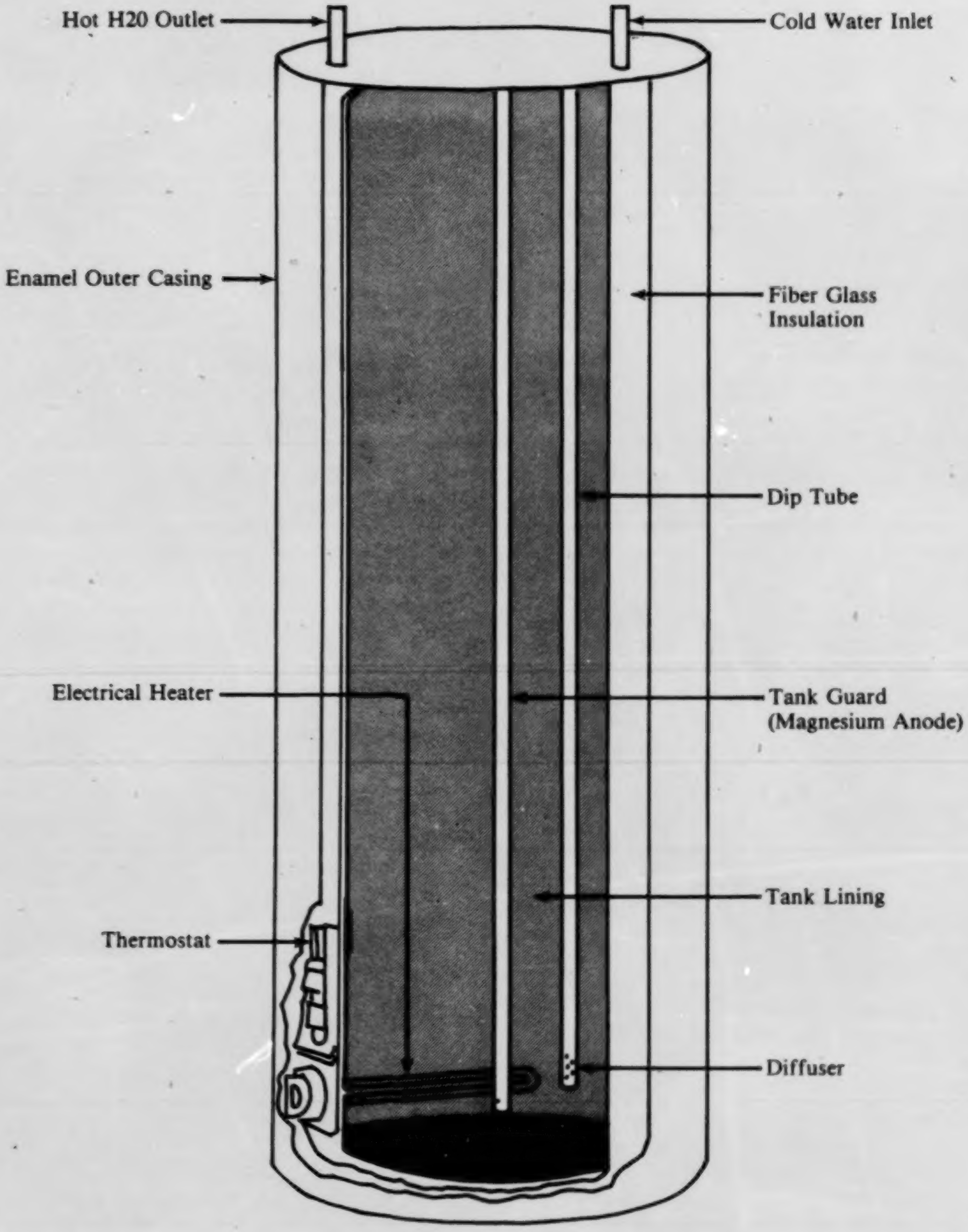

Figure 1. Water Heater

Table 3. **Estimated Disposition of the Annual Energy Input to Residential Water Heaters**

Type of Water Heater	% Total Heat Input	% Heat Lost Through Tank Surface	% Heat Lost Up Flue		% Net Usable Heat
			Burner Firing	Pilot Light [a]	
50-gallon electric	100.0	21.2	—	—	78.8
40-gallon gas/LPG	100.0	35.0	12.0	7.6	45.5
40-gallon fuel oil	100.0	35.0	13.5	8.0	43.5

[a] Assuming a 750 BTU/hr pilot and efficiency of heat transfer to the water of 70 percent for gas/LPG units and 67 percent for oil units.

Source: Residential Water Heating: Fuel Conservation, Economics, and Public Policy. Prepared for the National Science Foundation by James J. Mutch, R-1498-NSF, Rand Corporation, Santa Monica, Ca. May 1974.

Table 4. **Residential Water Heater Tank Insulation: Minimum-Cost Thickness, Economic Benefit, and Energy Benefit with Present Range of Energy Prices.**

Item	Factory-Installed Insulation			Retrofitted Insulation		
	50-Gallon Electric					
Electricity price (¢/kwh)	1	2	4	1	2	4
Minimum-cost insulation	4"	5"	7"	2"	2"	6"
Annual cost saving	$1.40	$4.00	$10.10	--	--	$4.90
Annual electricity saving(percent)	8.1	9.5	11.0	--	--	10.4
	40-Gallon Natural Gas/LPG					
Natural gas price (¢/therm)	10	20	40	10	20	40
Minimum-cost insulation	3"	4"	5"	1"	3"	4"
Annual cost saving	$2.90	$7.90	$15.50	--	$2.50	$10.70
Annual gas saving (percent)	21.6	23.8	25.0	--	21.6	23.8
	40-Gallon Fuel Oil					
Fuel oil price (¢/gallon)	20	30	40	20	30	40
Minimum-cost insulation	4"	4"	5"	3"	3"	4"
Annual cost saving	$4.80	$7.90	$11.20	$0.70	$3.50	$6.60
Annual oil saving (percent)	23.8	23.8	25.0	21.6	21.6	23.8

[a] Based on 10-year lifetime and an inflation-free, after tax discount rate of 8 percent.

Source: Residential Water Heating: Fuel Conservation Economics, and Public Policy. Prepared for National Science Foundation by James J. Mutch, R-1498-NSF, Rand Corporation, Santa Monica, Ca., May 1974.

Pilot Light Loss. When the fossil-fuel fired water heater is "off," energy is still consumed by the pilot burner. It has been claimed that the gas consumption of the pilot light, amounting to as much as 1,000 BTU per hour, is not really a loss since it does keep the water in the tank warm between "draws." If, however, the tank were adequately insulated and a flue gas damper installed, the contents would remain warm during a period of no water withdrawal with little heat input.

Manufacturers have been developing electric ignition systems which are simple, inexpensive, safe, reliable, and require little maintenance. Electric ignition systems have been successfully used for some time on gas-heated clothes dryers. Probably in the not too distant future, electric ignition systems will be commonly used on gas water heaters also.

Loss of Conditioned Air Between Burns. Conditioned room air is lost up the flue of an oil- or gas-fired water heater between burns, i.e., when the burner is off. Sensible heat in the heater metal and contained water is also carried away with the air which flows up the flueway. Reducing the size of the main burner orifice will lengthen the duration of the burn periods. This means the water heater will be on standby fewer hours each day, and this will reduce the standby heat loss. The loss can be cut by taking the combustion air from outdoors, either installing the heater out of doors or leaving it indoors but conveying the outside air through ducts to the combustion chamber and to the barometric damper or draft hood.

Reducing the diameter of the flueway also reduces the amount of air passing up through the heater during standby periods. Some conditioned air will still be lost through the draft hood or barometric damper.

Another way to reduce the loss of warmed room air between burns is to install a damper which automatically closes off the flue when the main burner shuts off. A small opening is provided in the damper to permit the combustion products from the pilot burner to be carried off. A standard published by the Z21 Committee of the American National Standard Institute (ANSI) permits installation of an automatic flue gas damper on the water heater at the factory. Retrofitting a damper to equipment already in use is thought to involve some risks; if improperly done, it could permit noxious gases to be discharged into living spaces. Accordingly, the Z21 Committee has opted not to publish a standard to cover retrofitted dampers. Without such a standard, the American Gas Association Laboratories (AGA) will not test or certify any of the dampers now available. Without AGA Laboratories certification, local code authorities will not permit retrofit installation of the devices. Such installation is permitted in six European countries where over 2,000,000 dampers are now in use in space and water heating appliances.

Many water heater manufacturers are already producing more efficient models. Soon all manufacturers will be doing so because of the Energy Policy and Conservation Act. This act directs the National Bureau of Standards (NBS) to recommend, and the Federal Energy Administration (FEA) to establish, an efficiency target for water heaters. If these targets are not voluntarily met by the water heater industry, FEA may then establish minimum efficiency standards.

Piping Systems

Heat losses from piping can be reduced by the following measures: adding insulation; reducing pipe size; reducing pipe length, making pipe runs more direct and locating the water heater nearer the water outlets with the greatest demand; reducing water temperature; providing two separate distribution systems; one carrying water at about 110° which is adequate for washbasins, baths, and showers, and the other carrying water at 150° needed for the dishwasher, and by combining hydronic space heating system with service hot water system. The first and last named of these possibilities warrant comment here.

Heat is lost from uninsulated hot water piping which carries heated water from the heater to the point of use in the home. When the hot water faucet is initially opened, one must let the water run for a short time until warm water issues forth. After the desired quantity of hot water is drawn off, the faucet is turned off again. The piping and its contents start immediately to cool. The rate of cooling depends upon ambient temperature, air currents, etc. Whether the piping system falls to ambient temperatures depends on how soon another need for hot water occurs.

Author has been unable to find in the literature data collected on a sizable sample of homes covering actual flow rates and frequency of hot water withdrawals and on temperature decay curves for the piping systems.

Engineers at Oak Ridge National Laboratory (ORNL), however, have made estimates of the savings potential on the basis of postulated water use patterns and piping heat loss characteristics.

Three daily water use schedules were selected by them: (A) a home that is vacant during normal working hours, (B) a home where the mother and children are at home during the day, and (C) a home having uniform intermittent usage throughout the day. The installed cost of the insulation was also estimated and compared with the capitalized value of the reduction of energy consumption. Because of the difficulty of typifying the plumbing layout for a home, all estimates were on a per-foot-of-pipe basis. The results are as follows:

	Heat Loss, kWh/yr/ft of Pipe			Break-Even Electricity Cost, Cents/kWh
Schedule	Bare	Insulated	Saving	
A	9.4	7.3	2.1	3.7
B	12.1	9.9	2.9	3.6
C	16.5	13.6	2.2	2.8

The ORNL engineers concluded that, on the basis of the electricity and insulation costs prevailing in 1971, a strong case could not be made for recommending universal adoption of insulated hot water piping.

In winter some space heating energy is lost to bare cold water piping in the home. For example, the water discharged when the toilet is flushed is warmer than the water which enters the home. In summer, in an air conditioned home, the water passing through the cold water piping systems and drains leaves the house colder than when it enters. This also represents an energy loss. It is doubtful that the insulation of cold water piping to prevent these losses would be economically justified.

Insulation is appropriately applied to the vertical piece of piping rising from the top of the heater. If this is not insulated, the hot water in this pipe during standby periods will be cooled by the ambient air and then sink back into the heater setting up a convection current which will in turn bring up more hot water. As an alternate to insulation, the hot water piping could be taken from the heater horizontally through a side outlet nozzle or through a horizontal run of pipe connected to an elbow mounted directly on the top of the heater.

Sizable energy savings are claimed for a system wherein the service water system and the hydronic space heating system are combined. The same hot water which circulates through the space heating coils is also the service water supplied to sink and tub faucets and showerheads. The circulating water is at a temperature of 140°. By varying the speed of the fan in each air handling unit, room temperature is held at the desired value. Piping heat loss is minimized because of the shorter total length of pipe and the moderate temperature employed. Heating plant losses are reduced because there is only one piece of heating equipment rather than two. This system has become popular for multi-family housing in California.

Before leaving this subject of piping, mention should be made of a system which permits the individual to obtain almost immediately a predetermined flow rate and temperature by simply pushing a button. A console containing banks of solenoid valves is located near the heater. Mixing of hot and warm water is accomplished there. A single 1/4-inch or 3/8-inch copper or plastic tubing carries water of the desired temperature to the fixture, eliminating the water and energy loss associated with adjusting a faucet by hand to obtain the flow and temperature desired.

Showers

The National Bureau of Standards reports that bathing accounts for 42 percent of the total daily usage of hot water in a residence. Showers are perhaps the most popular form of bathing.

A sizable energy saving can be obtained by reducing the amount of hot water used in showers. With respect to new construction, an important step in this direction has already been taken.

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) last year issued a standard 90-75, Energy Conservation in New Building Design. It is believed that this standard will be adopted in all states and applied to all new buildings. It contains the following requirement:

> **Conservation of Hot Water**
> Showers used for other than safety reasons shall be equipped with flow control devices to limit total flow to a maximum of 3gpm (1.9 x 10^{-4}m3/s) per shower head.
>
> Lavatories in restrooms of public facilities shall:
>
> a. Be equipped with outlet devices which limit the flow of hot water to a maximum of 0.5 gpm (3.2 x 10^{-5}m3/s).
>
> b. Be equipped with devices which limit the outlet temperature to a maximum of 110°F. (43°C).
>
> c. Be equipped with self-closing valves that limit delivery to a maximum of 0.25 gal. of hot water (9.5 x 10^{-4}m3).

There is much that can be done with the existing inventory of showers. The reduction in hot water use can be accomplished by urging citizens to install a flow restrictor to limit the shower flow rate, and to reduce the duration of the time spent in the shower. It is not appropriate to recommend that people take fewer showers or reduce the water temperature selected.

Estimating the savings achievable is difficult because little is known about the characteristics of the shower heads presently in use nor about the user's showering practices.

When the valve is wide open, the full flow rate for the various makes of shower heads varies greatly, as shown in Table 5 -- from 3 gal/min for a Crane Crestmont Model 8-359-2, for example, to 10 gal/min for Chase Brass No. 3033. Pulsating shower heads exhibit still higher flow rates.

With regard to how the showers are actually used there is evidently a wide range of practices. Some individuals shower at least once a day, some never, preferring a bath instead or simply foregoing any body washing. The very old and the very young take baths in lieu of showers. Some individuals are in and out of their shower quickly. Others, particularly teenagers, may remain in the shower for 20 minutes or longer. Some turn the shower to the full-flow position, others open it only part way. Even in circumstances where the water supply is known by the shower user to be limited the amount of water consumed is not small. The U.S. Navy's Atlantic Manpower and Materials Analysis Center conducted tests in 1972 which developed the data shown in Table 5.

In the Water Encyclopedia published by the Water Information Center of Fort Washington, NY, it is said that a shower bath requires 30 to 60 gallons of water. In the case of a shower head flowing at 6 gal/min, this quantity might be consumed in 5 to 10 minutes.

The U.S. Department of Interior, Federal Water Quality Administration, published in December 1969, a report prepared by James R. Bailey, et al, of General Dynamics Electric Boat Division entitled, "A Study of

Table 5. Shower Flow Rate at 40 PSIG

Shower Head	Shower Head Sizing Guide	
	Manufacturer	Flow Rate gpm
Act-O-Matic	Sloan Valve	5.5
Boyd	American Std.	9.5
Victor	American Std.	10.0
Anystream No. 1 52240	Speakman	4.5
Anystream No. 2 52240	Speakman	4.5
Anystream No. 1 52250	Speakman	9.0
Anystream No. 2 52250	Speakman	7.0
Anystream No. 3 52250	Speakman	6.0
Brown 620-B	Chicago Faucet	8.0
Bubble Stream	Wrightway Eng.	4.0
Central Brass No. 3033	Central Brass Mfg.	3.0
Chase 188-355	Chase Brass & Copper	10.0
Crane Rainbow No. 8-2556	Crane Co.	5.5
Crane Capri 8-2550	Crane Co.	3.0
Crane Crestmont 8-3592	Crane Co.	3.0
Crane Crestmont 8-3590	Crane Co.	3.0
Crane Criterion 8-1561	Crane Co.	5.5
Dearborn	Dearborn Brass	7.5
Eljer	Eljer	6.0
Federal	Federal Huber	---
Gyro-Manystream	Gyro Brass Mfg.	---
Harcraft B-2	Harvey Machine	8.0
Homart 2091	Sears	---
Homart 2080	Sears	---
Indiana Brass	Indiana Brass Mfg.	---
Kohler K-7325	Kohler	---
Kohler K-7332	Kohler	---
Magic Fountain	Magic Fountain	2.8
Milwaukee "Premier"	Milwaukee Faucet	3.5
Sterling S-194	Sterling Faucet	6.0
Sure Flow 35	Sure Flow Brass Mfg.	3.0
Sure Flow 36	Sure Flow Brass Mfg.	4.5
Symmons Clear Flow	Symmons Eng.	3.5-7.0
Symmons Super Flow	Symmons Eng.	4.0-9.0
Universal/Rundle	Universal/Rundle	---
Wizard	Logan Mfg.	3.5-5.0
PP-15-020	Price Pfister	4.5
Morn 1533	Std. Screw	4.0

Source: Commercial Water Heaters: Electric Engineering Handbook. State Stove and Manufacturing Co., Inc., Ashland City, Tenn.; Henderson, Nevada.

Flow Reduction and Treatment of Waste Water from Households." The emphasis was on homes not connected to central sewerage systems. In this report, limiting flow valves for showers were discussed. The authors noted that some claimed a 50 to 70 percent saving in shower water use, but, for their own calculations, a figure of 6 gal/d per capita was selected, or a saving of 24 gal/d in a 4 member household. Here again, the savings figure arrived at does not reflect reduced shower durations.

Three years ago a test was run by the Washington Suburban Sanitary Commission (WSSC) on 25 single-family homes fitted with 40 flow restrictors which limited shower flow rate to 3 gal/min. Duration of showers was not controlled. Sizable water savings were observed: in December, the average saving per household was 50 gal/d and in January 30 gal/d. A small increase in water consumption was observed when shower flow restrictors were installed in 100 townhouses in Gaithersburg, Maryland, however, the circumstances prevailing suggest that this test result may not be meaningful.

It has been reported (ASHRAE Guide and Rate Book - Applications 1966-1967 page 982) that "the manufacturers maximum flow rating can usually be reduced up to 50 percent without adversely affecting the spray pattern of the shower head."

There are many devices available to limit the discharge flow rate of existing shower heads. We will mention only a few. The simplest and least costly solution is to install, in the showerhead itself or in the piping leading to it, a simple washer with a hole of appropriate size. The cost is but a few pennies. With a simple fixed orifice, however, the flow rate is proportional to the square root of the pressure. The opening of another fixture in the system may cause the shower water flow to drop below an acceptable level or may cause uncomfortable changes in the temperature of the water. Variations in main pressure are small in most communities but, in some cases, may present problems.

Flow restrictors are available which incorporate a variable orifice. A drop in line pressure causes the throat to open wider to maintain the flow relatively constant. These devices are rather costly, retailing for about $6, but the cost is soon recovered.

There is a third possibility falling midway between the fixed orifice and the washer with respect to cost and performance. It is a plastic venturi nozzle which can be inserted in the line to the shower. An increase in pressure upstream results in greater cavitation in the throat of the nozzle and in a smaller flow increase than would otherwise occur. It is not known whether a reduced flow rate causes a person to remain under the shower for a longer period of time. If it does, much of the savings achieved by the lower flow rate will of course be lost.

In the category of more sophisticated systems is a reduced flow shower system in which air supplied by a small blower passes through the shower nozzle breaking up the water streams into a spray pattern which simulates a conventional shower.

In bathing with a shower, water must penetrate the boundary layer of the skin to permit wetting down, soaping up and rinsing off. In a conventional shower, the motive force to achieve this comes from the water pressure which provides the spray droplets with the necessary kinetic energy. In this air-water shower, this motive force is supplied by the air from the blower.

The Naval Ship Research and Development Center on tests run at the U.S. Naval Academy field locker room in Annapolis, Maryland found that a satisfactory shower was achieved using only 0.5 gal/min or about 5 percent of the water normally used. An average of 1.7 gallons of water were consumed per shower as compared to 12.1 gallons for a conventional Navy shower at this facility. Ninety percent of the users reported satisfaction with the showers.

Faucets

A wide open sink faucet can discharge five gallons of water a minute. Significant water and energy savings can be achieved by installing at each sink, devices such as aerators and spray taps, to limit the water flow rate to lower values.

Aerators. Faucet aerators are in common use. In this device, air at atmospheric pressure is induced and mixed with the water. The water and air mixture gives the appearance of a larger water flow than is actually present. It has been estimated that faucet aerators reduce water consumption at bathroom sinks by approximately 25 percent. Alternately, flow restrictors similar to those used for showers can be installed with savings estimated also at about 25 percent.

Spray Taps. Spray taps discharge a fine spray of water at the sink in lieu of a solid stream of water. Tests conducted in office buildings indicate that spray taps produced large reductions in water consumption as compared to ordinary faucets. In one case, the savings was claimed to be in excess of 90 percent. Perhaps in residential applications where faucets are not equipped with an aerator, the savings will amount to 50 percent. Where aerators are already fitted, a savings of only 25 percent is possible through replacement with a spray tap.

The author's calculations suggest that installation of spray taps in the bathrooms in all home may yield an energy savings on the order of 20,000 BPD oil equivalent, assuming that one-half of the bathroom faucets today are equipped with aerators. An additional savings would be achieved by installing spray taps on kitchen and utility sinks as well.

At present energy prices, the spray tap would be cost effective especially in the case of new and existing homes equipped with electric hot water heating.

The potential savings resulting from installation of faucet aerators are about half that calculated for spray taps. The cost of the spray tap is far higher, particularly when installation is to be made in an existing home. Thus, aerators will continue to have a prominent place among water conservation devices offered in the market place.

Self-closing faucets also discourage excessive water use, but would generally not be acceptable for home use.

An excellent discussion of the economics of aerators, spray taps, and flow restrictors will be found in Water Conservation and Wasteflow Reduction in the Home, Special Circular 184 by William Sharpe, The Pennsylvania State University, University Park, Pennsylvania.

Energy Savings Through Use of Flow Restrictors

Data is not available on the amount of hot water saved through use of flow restrictors. Consider the case of the simple shower flow restrictor for example.If the average user adjusts his faucet to obtain a flow of 6 gal/min, then a 3 gal/min flow restrictor will cut energy use in half (assuming no increase in duration of the shower).

If the average user is presently adjusting the faucet to obtain only 3 gal/min, then installation of the same flow restrictor may save no energy at all.

Let us assume that flow restrictors are installed on all showers, basins, and sinks in every home and that these devices effect a warm water savings of 20 gal/day/home. The calculations included in the appendix lead to the results shown in the accompanying attachments C and D.

Of course, this potential probably cannot be fully realized because it is not possible to install a flow restrictor in every shower head. In some homes shower flow restrictors have already been installed or will have been installed.

In other homes, the occupants would simply not install the flow restrictors even if they were given to them free of charge. They may not know how to do it or may lack the necessary self-confidence. Or may fear that their shower would be less satisfactory. Or may be generally reluctant to try something new.

Or they may be renters disinclined totake any action that increases the landlord's profits. (In 1970 36 percent of the nation's housing was renter-occupied.)

It should, however, be possible to design a program which would bring about installation of flow restrictors in 75 percent of America's homes.

A similar program could be directed toward commercial and institutional buildings. A total energy savings in excess of 100,000 BPD should then be realizable.

WSSC has purchased 400,000 cavitating type flow restrictors for free distribution to customers requesting them. Data on the water savings resulting from this important pioneering program is unfortunately not available.

The International Association of Lions Clubs, Oakbrooke, Illinois, is presently engaged in a program involving the distribution of 1/4 million flow restrictors through local Lions Club throughout the country.

Bathtubs

There are several possible methods for decreasing the energy required for heated bathtub water. The tub could be insulated, perhaps with a strip of thermal insulation separating the inner tub from the outer tub wall. Its shape could be designed to conform more nearly to the shape of the human body, thus reducing the volume of water used. It could be made of material with a low specific heat.

Leaks

Regardless of the type of faucet employed or its location, a hot water leak which is not repaired results in energy waste.

Laundering

The women of developing countries who wash their clothes on a smooth rock by the riverside have no control over the water temperature. Women in more affluent lands who wash clothes indoors by hand or machine using piped water usually do have some control over water temperature. Over the years most of them appear to have preferred hot water. In the United States, hot water, at a temperature of 130°F in the tub, is commonly used. In Europe, the preferred temperature is about 180°F or even higher. Home laundering practices in the United States are approximately as follows:

	Percent of Wash Loads
Washed in hot water	30
Washed in warm water	50
Washed in cold water	20

Cottons and whites tend to be washed in hot or warm water, and permanent press and colored items tend to be washed in cold or cool water.

From the point of view of the individual family, hot water laundering is expensive. For a home with an electric hot water heater, one laundry load with a hot water wash and a warm water rinse accounts for an energy consumption of 4.2 kWh, and that represents over 3/10 gallons of fuel oil burned back at the power plant. At 3 cents per kWh, it involves an average cost to the consumer of about 13 cents. If the water is heated with gas at $1.25 per thousand cubic feet, the average cost of water heating for one load of laundry is almst 4 cents. If a hot water wash and a warm water rinse were used in every laundry load, the total annual cost would be about $15 for a home with a gas water heater and $52 for a home with an electric water heater. For laundering with a warm water wash and a warm water rinse, the costs drop to $10 and $35 respectively. For laundering with warm water and cold rinse, the costs drop to $5 and $18 respectively.

The potential energy savings of the nation are considerable. The author's calculations show that if we could wave a magic wand and stop all warm and hot water rinsing, the nation's energy consumption would fall by as much as 50,000 BPD oil equivalent. If we could wave the magic wand again and stop all hot water use in the washing step of the laundry process, the nation's energy consumption would fall by as much as 110,000 BPD more.

But energy and cost are not the only factors to consider, nor can the full theoretical potential energy savings be achieved, at least not with today's laundry products. Under some circumstances it is necessary to launder in hot water.

Biological Aspects. There are a great many ways in which disease can be transmitted from one person to another living in the same home: touching each other; touching common articles (doorknobs, for example); using cutlery and dishes washed together; sneezing and coughing.

No documented cases are known wherein disease has been transmitted through home laundering, but we know of no epidemiological investigations having been performed on the subject. The public health threat created by washing in cold water is probably minimal. The above notwithstanding, there are some aspects of cold water laundering which warrant our attention.

In laboratory tests, a wide variety of bacteria and viruses have been found in finished laundry, and in the wash water and rinse water. Some of these microbes are capable of causing disease in human beings. Among the harmful bacteria are:

> *Staphylcoccus aureus*, frequently known as staph. This can cause boils, carbuncles, skin infections, respiratory infections, kidney infections, and other types of infections.
>
> *Pseudomonas aeruginosa*, frequently known as the green pus producer. This can cause skin and kidney infections. It is often present in chronic infections of the middle ear.
>
> *Paracolon bacteria*. Some of the bacteria in this family produce intestinal disturbances.

Vigorous washing in hot water and drying will not assure that the laundry is freed from such pathogens.

Many more bacteria survive cold water laundering than either hot or warm water laundering. Data collected by one investigator indicated that, at washing temperature between 115°F and 135°F, many micro-organisms are killed. Another concluded that 140°F is about the critical point below which killing of vegetative bacteria is not complete. Temperatures of 150°F and above will kill almost all bacteria.

Of course temperature is not the only factor affecting bacteria kill in laundering. Washing and rinsing time, type and quantity of detergent, alkalinity, amount of agitation, time and temperature in the dryer, and type of cloth are all factors to be considered.

When cold water washing is employed, more bacteria will be present on the inner surface of the machine, i.e., tub wall and agitator. Bacteria can be transferred from one load of clothes to the machine and from the machine to another load of clothes.

One investigator concluded that residential-type automatic clothes dryers can be depended upon to reduce the number of bacteria. Moreover, this effect was so pronounced that drying in an automatic dryer obscured the effect of wash water temperature. But this is not a universally accepted conclusion. Another investigator concluded that tumble drying at a delicate setting could not be relied upon for sanitation. Several decades ago, still another investigator concluded that tumble dryers used in commercial laundering appeared to have little sanitation effect.

If it is desired to kill all germs in the water and on the clothes thus obtaining maximum protection against the spreading of infection, then a quarternary or liquid chlorine disinfectant should be added to the wash or rinse water. This is true whether washing is performed in hot water or cold.

It is the author's conclusion that cold (or warm) water laundering without a bactericide is appropriate and poses no serious threat to health where (a) all members of the family enjoy reasonably good health, and (b) where the clothes after laundering will be dried in a dryer or outdoors on the line. Comments by Public Health authorities on this conclusion are invited.

Cold or warm water laundering without a bactericide is not appropriate where any of the following applies:

> A member of the family has a communicable disease, boils or skin infection;
>
> Laundry contains fecal matter, such as baby's diapers;
>
> Drying will be performed at room temperature with out exposure to sunlight, such as in a bathroom or basement.

It is generally accepted within the detergent and the washer industries and among home economists that rinsing of clothes in hot or warm water is completely unnecessary. There is also fairly general agreement that clothes washed in hot water look cleaner and actually are cleaner than clothes washed in cold water.

The difference can be very small however. Many people who regularly employ cold water laundering are quite pleased with it. Evidently they cannot detect the difference or, if they do see it, are content to accept it. Consumers Union writing in an article appearing in their 1974 issue stated:

> Hot water has always been expected to wash better, but we could only prove it with our instruments in most cases. Instruments usually showed only a slight percentage difference between hot- and cold-water washings–a difference you probably wouldn't be able to see.
>
> We liked the results of our cold-water wash well enough to suggest you give it a try. Depending on how you heat your water, you can save up to $50 or so a year. And if the nation could save about $2-billion in energy that simple way, the rewards make even more sense. At the same time, you'll never suffer the inconvenience of running out of hot water during laundering. And you may prolong the life of your washables (cool water is generally kinder to most fibers than hot water is).

The above notwithstanding, many people have tried cold water laundering and found it to be unsatisfactory. These dissatisfied users are more apt to be those whose laundry is heavily soiled with grease, those living in areas where the cold water temperature in winter falls into the 40° to 59° range, and those living in areas where the law permits selling only detergents which are phosphate free.

When the theoretical energy savings potential given previously is discounted to reflect these realities, there still remains a potential energy savings total clearly in excess of 100,00 bbl/d. Accordingly, the federal government has made an effort to induce the American people to rinse in cold water always and wash in the coolest water (cold, warm, and occasionally hot) which will yield a satisfactory result.

Table 6. Specifications and Performance of Washing Machines *

	Regular Cycle (1) Water Used (hot wash/cold rinse)		Durable-Press Cycle(1) Water Used (warm wash/cold rinse)		Presettable Combinations Temperatures (wash/rinse)
	Hot (2)	Total (2)	Hot	Total	
Whirlpool LAA 5800	24 gal	51 gal	15 gal	71 gal.	H/W,H/C W/C,C/C
Whirlpool LAA5805	24	51	15	71	H/W,H/C W/C,C/C
Maytag A207S	16(27)	37	8	49	H/W,W/C,C/C(3)
Hamilton WA 373	25	52	9	56	H/W,H/C,W/W W/C,C/C
Frigidaire WCD3T	23	55	13	63	H/W,H/C W/W,W/C
Gibson WA83312A	24	48	12	54	H/W,H/C,W/W W/C,C/C
Sears Kenmore 32611	16(30)	35(39)	10	44	H/W,W/C,C/C
Wizard Citation 5WC2340	25	53	12	53(4)	H/W,H/C,W/W W/C,C/C
Blackstone BA702	20	46	10	56	H/W,H/C W/C,C/C
Norge LWA2050	24	53	11	53(4)	H/W,H/C W/C,C/C
Kelvinator W624G	25	52	9	56	H/C,W/W W/C,C/C
Westinghouse LA470P	23	60	12	54(5)	H/W,H/C,W/W W/C,C/C
Wards Signature 6224	23	50	10	50(5)	H/W,H/C W/C,C/C
General Electric WW-A7030P	22(34)	45	11	45(6)	H/W,W/C,C/C
Hotpoint WLW2600	9(20)	36	5	36	H/W,W/C,C/C
Speed Queen DA6123	23	41	8	42(4)	H/W,H/C,W/W W/C,C/C

(1) Water pressure at 40 psi with 8-lb load and maximum fill. Variations among samples of the same model may cause variations of 1 or 2 gal.

(2) Figure is for hot wash/cold rinse. Where this combination is available only by resetting temperature control after wash fill, the gals. used if not reset are shown in parentheses.

(3) H/C, W/C, C/C on durable-press cycle.

(4) Regular cycle is used for durable press.

(5) Short cycle is used for durable press.

(6) Using regular cycle, judged preferable to "permanent-press" cycle.

KEY: H-Hot; W-Warm; C-Cold.

* SOURCE: Consumer Reports 1975 Buying Guide, p.66. Published by Consumers Union of United States, Inc., 256 Washington Street, Mt. Vernon, N.Y. 10550. December 1974.

Public Education. Clothing manufacturers provide labels on garments made of synthetic fibers and on those made with a permanent press warning against use of hot water. This practice helps. Indeed, these labels have probably done more to discourage hot water laundering than any other measure.

In the current edition of FEA's Tips for Energy Savers the advice is given:

Wash clothes in warm or cold water, rinse in cold.
You'll save energy and money. Use hot water only if absolutely necessary.

In the Fact Sheet accompanying President Ford's "Program to Control Inflation in a Healthy and Growing Economy," October 8, 1975, it was announced that "the Administration will...encourage everyone to use cold water for laundry."

The copy on one laundry product states the case for cold water laundering.

Safe for all washable fabrics
Colors stay bright
Reduces wrinkles
No hot water stain setting
Washable colors won't run or fade
Conserves hot water
Saves on hot water heating bills

The containers for many other detergents, however, are primarily performance oriented, and they fail to call attention to the energy and cost savings advantages of cold water laundering. While they do provide instructions on washing in warm or cold water garments which would be damaged in hot water, they clearly suggest hot water washing should be used whenever possible. Here are some examples of the copy on boxes of well-known detergents:

> Hot water...gives the quickest and best cleaning performance.
>
> Use the warmest water temperature recommended by the manufacturer.
>
> Use Proper Water Temperature--for white and fast colors, use hottest water available.
>
> Use hot water for washing regular white and colorfast family loads, especially if they are heavily soiled.
>
> Select right temperature and wash-time settings..in fabric you are using.

In February 1975, Roger Sant, Assistant Administrator for Energy Conservation and Environment, the Federal Energy Administration appealed to the manufacturers to revise copy on detergent containers. He asked that an additional line or two be added to remind the housewife that washing in hot water consumes more energy and raises her electric or gas bill. With such a reminder, the individual housewife is more likely to make the right decision as to the proper temperature for her.

A recent survey of the detergent section of the author's neighborhood supermarket discolosed that many labels have been revised. The products of one manufacturer bore labels recommending only cold water for rinsing regardless of wash temperatures. Some products however, are still "pushing" hot water washing; while others present a more balanced picture. With one or two exceptions, none have called attention to the savings in monthly energy bills resulting from use of warm or cold water.

In closing our discussion of this opportunity for energy savings, it is appropriate perhaps to observe that is cold water laundering with today's products does, in some cases, result in a materially inferior cleaning or sanitizing job as compared to hot water laundering, then it is appropriate that an intensive R&D effort be carried out to develop a detergent which will yield the desired result in all circumstances. It is believed that such an effort is already in the laboratories of the leading detergent manufacturers.

Meters and Load Controllers

Metering can have a significant effect upon hot water consumption. In most rental apartment houses, the tenant does not pay directly for the hot water he uses. It is likely that if his hot water consumption were separately metered and billed, he would use hot water more prudently.

The peak system demand for most electric utilities occurs in the late afternoon and early evening hours. To meet this peaking demand, the utility must place in operation inefficient equipment, usually combustion gas turbine generators or older steam plants. The consumption of fuels in the electric utilities' generating stations would be reduced by minimizing hot water usage during the peak load hours. This means postponing laundering, dishwashing, and showering until after the system peak load has passed. The average consumer would be unwilling to accept this inconvenience unless some incentive were offered such as a lower electricity rate. Metering systems to provide for dual billing rates are available. Also available are residential load controllers to turn off the electric heater during periods of peak electric demand. A number of electric utilities have initiated programs to demonstrate reliability and economic feasibility of these devices.

Appliances

The hot water consumption of a clothes washer and of a dishwasher can be significantly reduced. One appliance manufacturer has observed that three kinds of energy are supplied to washers: thermal energy in the form of hot water, mechanical energy in the form of agitator motion, and chemical energy in the form of a detergent. In the case of a dishwater, energy is added in three forms also: thermal energy in the form of hot water supplemented by the machine's own electric heater, mechanical energy in the form of water spray, and chemical energy in the form of a detergent.

The total energy input should be minimized. One way to achieve this may be by reducing thermal energy input and increasing the input of mechanical and chemical energy.

But be that as it may, the individual today can insure mimimum consumption of hot water by exercising care in purchase of a new washer or dishwasher.

First of all, inquiry should be made of the amounts of hot water and electricity required to complete the normal cycle of operation. As Table 6 indicates, there are differences in these respects among the various washers on the market. The buyer should be especially careful that the automatic controls on the machine he buys will permit rinsing to be performed in cold water regardless of the temperature selected for the wash part of the cycle.

The washer should be equipped with a suds-saving device. This permits reuse of the warm water from the first load for the washing of the second load. Unfortunately, most washers sold today lack this feature.

The design of the washer should permit a partial filling of the tub when less than a full load of wash is to be done. Where the machine lacks this feature, the homemaker should postpone laundering until a full load of clothing has accumulated. FEA, through its publications, is attempting to educate Americans to do this.

In buying dishwashers, it is also advisable to look for energy-saving features. For example, a switch should be provided so that the drying element can be switched off. When this feature is not available, the user can accomplish the same result by opening the door of the dishwasher after the washing portion of the cycle is completed. The electric heater will remain off, but the dishes will dry nevertheless.

Incidentally, in an April 3, 1975, news release, a prominent appliance manufacturer announced a new line of dishwashers which require 18 to 27 percent less energy than the older models they replaced.

Under the Appliance Efficiency Improvement Program authorized by the Energy Policy and Conservation Act, all manufacturers are being called upon to upgrade their products by 1980. The average energy requirements for new washers will be appreciably below the present value.

Heat Recovery

It is possible to utilize waste heat for heating water in the home. Drainage pipes from laundry, dishwasher, shower and bath can be insulated and carried to a heat exchanger where the sensible heat in the waste water is transferred to the fresh incoming water. Among the practical problems involved are the cost of the heat exchanger, the need to keep the waste water side of the heat exchanger reasonably free of fouling and the reluctance of public health authorities to approve an apparatus which could conceivably result in contamination of the fresh water supply.

It is possible, also, to use the heat rejected by air conditioners, refrigerators, and freezers to heat incoming water. However, doing this would raise the installed cost of these appliances substantially.

Burning garbage and trash fuel in an auxiliary water heater would save fossil fuels, but would involve an additional capital expenditure to purchase a heater with the necessary pollution control equipment. It would also introduce an undesirable chore--the periodic clean-out of the firebox.

Installing a 'tempering' tank or coil in the basement would be beneficial. The air in the basement is warmed by the heat lost from the outside of the heating furnace, the water heater, and their flues, and from heat passing down through the basement ceiling from the heated living space above. If the cold incoming water is permitted to stand for a time in the basement and be warmed, the heat load on the water heater will be reduced, probably with a net savings in the overall energy consumption of the house.

It is possible also to preheat incoming water by drawing it through attic pipes during those hours of the year when the attic is hot due to solar radiation.

Oak Ridge National Labs found that, in a locale having the same annual average air temperature as Knoxville, and an average water supply temperature of 70°F, a 15-foot-long finned heat recovery tube could save 370 kWh/year. On the basis of a 1971 installation, it would be economical at a cost of 4 cents per kWh. It would, of course, also be worthwhile in areas having higher annual average water temperatures and/or longer summers. The conclusion was reached by the ORNL investigators that "the potential for energy and monetary savings with the attic preheater appears small."

Solar Hot Water Heating

The energy of the sun can be used for heating water. Domestic water heating is economically the most attractive application for solar energy utilization in residences; it offers low fixed costs per unit of solar energy collected and is needed year round. In contrast, when solar energy is used for space heating applications and space cooling applications, the equipment is costly and is used for only a part of the year.

In a conventional solar water-heating system, solar energy is collected by a blackened copper pipe mounted in a shallow airtight box. The box is covered with glass and is installed on the roof of the house. A storage tank is provided indoors. The technology to build good solar heaters already exists. Indeed, tens of thousands of solar heaters installed in Florida homes have operated successfully for many years. Only the advent of low-priced natural gas has brought about a discontinuance of their sale.

A complete solar water-heating system can be installed for about $1,200 in most parts of the United States. On days when the sun shines brightly, it will supply the hot water needs of a typical family. Unfortunately, the sun does not shine every day so that a conventional water heater must be installed also as backup.

The payout periods for a solar system will vary with insulation, climate, interest rates, and the prevailing price of fossil fuels. With the rapidly rising cost of electricity and fuel oil, one might conclude that solar heaters will very soon take over all of the nation's domestic water heating. There are two important factors which today are slowing the growth of solar water heating. Installation of a solar water heater raises the purchase price of a new home, and this is something which the home buyer and the builder try to avoid. Similarly, the initial cost discourages the installation of solar water heaters in existing homes. To help overcome this resistance, the federal government has urged

Congress to enact legislation which would offer an income tax credit to homeowners who install a solar hot water heater or solar space-heating equipment.

A second important factor discouraging installation of solar water heaters in existing homes is the prevailing high interest rates which must be paid on borrowed funds. For many locations of the United States, annual payments for interest and repayment of the principal exceed the value of the fossil fuel saved.

The federal government is attempting to bring about a lowering of interest rates. In the coming years the price of fuels and electricity will probably continue to rise, while interest rates will almost surely fall. And thus, eventually, the solar water heater will come into its own.

The author would like to suggest that the choice of a water heater's fuel should not be simply a matter of first cost or even of life cycle costs. Perhaps solar energy should be utilized for water heating simply because it represents an effort to conserve fuel for future generations.

After all, in consuming fossil fuels, we are consuming our inheritance - the energy received from the sun ages ago and stored in once living matter buried deep in the earth. We should learn to live on our income.

We, as a people, spend large sums supporting the arts, sending men to the moon, preserving wilderness areas, cleaning our rivers, etc., and there is no financial payout for these actions. Why not install solar water heaters simply because this slows depletion of a diminishing nonrenewable natural resource? Why not install solar water heaters simply because it is the right thing to do?

INDIRECT ENERGY SAVINGS RESULTING FROM REDUCTION IN RESIDENTIAL WATER USAGE

There is a significant energy use in the pumping, filtration, chlorination, and other treatment, and distribution of municipal water supplies. Pumping energy alone is on the order of 38,000 BPD. Similarly sizable amounts of energy are consumed in handling and treating sewage from homes.

It can be stated with confidence that general reduction in residential consumption of hot and cold water will produce energy savings at the water works, sewage treatment plants and in the plants manufacturing water and sewage treatment chemicals.

In this area, as in the others, we have touched upon there is much work to be done - to determine how much energy is being consumed and in what manner and to evaluate the various methods for reducing that energy consumption.

It is the author's hope that this paper will cause research organizations and others to direct their attention to this important yet still largely unexplored energy field.

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CALCULATIONS TO DETERMINE ENERGY USED IN LAUNDERING AT HOME

Assumptions

Annual Average--	
temperature of water supply to house	60°
temperature of water leaving heater	130°
temperature of hot water entering washer	120° (not used)
temperature of cold water to washer	60° (not used)
temperature of warm water to washer	90° (not used)
Average number of loads in week	8
Percent of loads using hot water for washing	30%
Percent of loads using warm water for washing	50%
Percent of loads using cold water for washing	20%
Percent of loads using warm water for rinsing	50%
Percent of loads using cold water for rinsing	50%
Efficiency of average fossil fuel fired water heater for incremental output *	50%
Efficiency of average electric water heater for incremental output *	100%
Warm water is a 50-50 mixture of hot water and cold water	

Average of all actual fills for the nation in washers of all types in 17.0 gallons.

For the U.S. as a whole, 11,600 Btu of fuel must be consumed in a power generating station in order that 1 Kwh can be delivered to a home.

Water weighs 8.33 pounds per gallon and has a specific heat of 1.0.

Calculations

Let us consider first the energy used in laundering with hot water.

Energy added to water in hot water heater to provide for one laundry load with hot water:

17.0 gals x 8.33 lb/gal x 1.0 x (130-60) = 9,900 Btu/load

Energy in fuel burned in gas fired hot water heater to heat this water:

$\frac{9{,}900\ \text{Btu/load}}{.50} = 16{,}500\ \text{Btu/load} = 132{,}000$ Btu/week = 6,850,000 Btu/year

At $1.25 per million Btu, this represents a cost of 2.06 cents/load or 16.5 cents per week, or $8.55 per year.

Energy in electricity consumed in electric hot water heater at 100% efficiency to heat this water:

$\frac{9{,}900\ \text{Btu/load}}{1.0} \times \frac{1\ \text{Kwh}}{} = 2.9\ \text{Kwh/load} =$

23 Kwh/week = 1,210/year

at 3 cents/Kwh, this represents a cost of 8.7 cents/load, or 70 cents/week, or $36.20/year.

Fuel burned in the power plant to serve this electric load:

$2.9\ \text{Kwh} \times \frac{11{,}600\ \text{Btu}}{1\ \text{Kwh}} = 33{,}600\ \text{Btu/load} =$

269,000 Btu/week = 14,000,000 Btu/year

For a warm water washing the energy cost figures will be one-half of those calculated above.

For a warm water rinse, the energy cost is also one-half of the foregoing figures.

Gas Water Heater

For one hypothetical machine representative of the entire United States:

Washing

For 30% of loads washed in hot water, the fuel energy consumption is:

6,850,000 Btu/year x .30 = 2.05 x 10^6 Btu/year/washer

For 50% of loads washed in warm water, the fuel consumption is:

.50 x 6,850,000 Btu/year x .50 = 1.71 x 10^6 Btu/year/washer

Total consumption for wash water heating:

(2.05 × 1.71) x 10^6 = 3.76 x 10^6 Btu/year/washer

Rinsing

For 50% of loads rinsed with warm water:

.50 x 6,850,000 x .50 = 1.70 x 10^6 Btu/year for warm water rinsing

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* This figure is applicable to increases or decreases in heater output. It is assumed that heat losses through inner and outer tank walls is not changed by virtue of the change in water throughout.

Both Washing and Rinsing

Total fuel consumption for hot and warm washing and warm rinsing:
$3.76 \times 10^6 + 1.70 \times 10^6 = 5.46 \times 10^6$ Btu/year, say
5.0×10^6 Btu/year/washer
or the energy equivalent of almost 1 barrel/year/washer

Electric Hot Water Heater

For one hypothetical machine representative of the entire United States:

Washing

For 30% of loads washed in hot water, the power plant fuel consumption would be:
1,210 Kwh x 11,600 Btu/Kwh x .30 = 4.2×10^6 Btu/year
For 50% of loads washed in warm water, the power plant fuel consumption would be:
605 Kwh x 11,600 Btu/Kwh x .50 = 3.5×10^6 Btu/year
Total energy used for washing = 7.7×10^6 Btu/year/washer

Rinsing

For 50% of loads rinsed in warm water, the power plant fuel consumption would be:
605 Kwh x 11,600 Btu/Kwh x .50 = 3.5×10^6 Btu/year

Both Washing and Rinsing

Total fuel consumption for hot and warm water washing and warm rinsing:
$(7.7+3.5) \times 10^6 = 11.2 \times 10^6$ Btu/year/washer
or, the energy equivalent of almost 2 barrels/year/washer

For The Nation

According to the Census of Housing Series HC (1) B Table 34:

Homes with a washer in 1970 (automatic, semi-automatic, wringer or spinner	45,100,000
Homes with electric water heater	16,100,000
Homes with gas, oil or coal water heater	44,600,000

Assume all homes with a washer have a water heater also. Then, the total number of washers served by electric water heaters is 16.1 million. The total number of washers served with a direct fired heater is by difference (45.1 - 16.1) million or 29 million.

Energy Consumed at the Nation's Power Plants to Produce the Electricity Required by Electric Water Heaters in Heating the Water Used in Home Laundering.

For Washing only

7.7×10^6 Btu/year/washer x 16.1 x 10 washers
$= 12^4 \times 10^{12}$ Btu/year
= 59,000 BPD

For Rinsing Only

3.5×10^6 BTU/year/washer x 16.1×10^6 washers = 56.5×10^{12} Btu/year = 27,000 BPD

Total for Washing and Rinsing

59,000 x 27,000 = 86,000 BPD

Energy Consumed in the Nation's Homes for Laundering Clothes Using Hot Water Obtained from Water Heaters Burning Gas, Oil or Coal.

For Washing Only

3.76×10^6 Btu/year/washer x 29×10^6 washers
$= 109 \times 10^{12}$ Btu/year
= 51,000 BPD

For Rinsing Only

1.7×10^6 Btu/year/washer x 29,000,000 washers
$= 49.2 \times 10^{12}$ Btu/year
= 23,000 BPD

For Washing and Rinsing

51,000 + 23,000 = 74,000 BPD

Grand Total Energy Use for Heating Water in America's Homes for Laundering

86,000 + 74,000 = 160,000 BPD

We can adjust this result to 1975 by assuming the energy consumption rose in proportion to the number of households and that the ratio of new electric heaters to new fossil fuel fired heaters was the same as in the 1970 inventory, then:

$$160{,}000 \text{ BPD} \times \frac{71.9 \times 10^6}{63.8 \times 10^6} = 180{,}000 \text{ BPD}$$

The heated water total energy for home laundering today.

The total energy used for washing only is:

$$(59{,}000 + 51{,}000) \times \frac{71.9 \times 10^6}{63.8 \times 10^6} = 124{,}000 \text{ BPD}$$

The total energy used for rinsing only is:

$$(27{,}000 + 23{,}000) \times \frac{71.9 \times 10^6}{63.8 \times 10^6} = 56{,}000$$

The foregoing analysis assumes that for the Nation as a whole the cold water temperature averages 60°F and the hot 130°F yielding a rise of 70°.
If the average cold water temperature is 67° the ΔT becomes 63°.
The energy rise then is reduced by 6%.
The total energy used for hot and warm water washing only becomes
124,000 BPD x 63/67 = 117,000 BPD.
The total energy used for warm water rinsing becomes
56,000 x 63/67 = 53,000 BPD.

$$2 \text{ showers/day} \times \frac{10 \text{ gallons saved}}{\text{shower}} \times \frac{8.33 \text{ lbs}}{\text{gallon}}$$

$1.0 \times (105° - 60°) = 7.5 \times 10^3$ BTU saved/day, or 365 days/year $\times\ 7.5 \times 10^3$ BTU/day $= 2.74 \times 10^6$ BTU/year.

For a water heater fired by gas or oil with an efficiency of 50%, the fuel saving is:

$$\frac{2.74 \times 10^6 \text{ BTU/year}}{.50} = 5.48 \times 10^6 \text{ BTU/year or } 39.5$$

gallons of oil/year.

For the nation as a whole this means a fuel savings of:
$.85 \times 44 \times 10^6$ homes $\times\ 5.48 \times 10^6$ BTU/year/home = 205×10^{12} BTU/year, or 96,000 BPD

For an electric water heater, the electricity saved per home is:

$$2.74 \times 10^6 \text{ BTU/year} \times \frac{1 \text{ KWH}}{3413 \text{ BTU}} = .80 \times 10^3$$

KWH/home/year.

For the 16 million homes with electric hot water heaters the savings is:
$.80 \times 10^3$ KWH/home $\times\ .95 \times 16 \times 10^6$ electric homes $= 12.2 \times 10^9$ KWH/year.

To serve a load of this magnitude the nation's power stations will consume energy equal to:

$$12.2 \times 10^9 \text{ KWH} \times \frac{11{,}600 \text{ BTU}}{1 \text{ KWH}} = 142 \times 10^{12}$$

BTU/year = 67,000 BPD.

The total theoretical potential saving in fuel of all kinds is:
96,000 + 67,000 = 163,000 BPD including oil, gas, coal, hydro, nuclear. About 33 percent of the electricity distributed by the nation's utilities is derived from oil and gas, thus, the oil and gas saved in power stations is approximately 1/3 x 67,000 = 22,000 BPD.

The total theoretical potential fuel savings in the form of oil and gas only is:
96,000 BPD + 22,000 BPD = 118,000 BPDOE as oil and gas.

Effect on Homeowner's Energy Expenditure

A 20 GPD reduction in the amount of warm water used in showers will result in a noticeable drop in energy bills for the individual family.

	Hot Water Heater		
	Gas fired	Oil fired	Electric
Annual energy savings per home	55 therms	40 gallons	800 KWH
Annual savings in energy bill per home			
gas at $1.50/therm	$8.25		
heating oil at 40 cents/ gallon		$16.00	
electricity at 3.0 cents/ KWH			$24.00

Attachment A **Shower Flow Rate at 40 PSIG**

	Shower Head Sizing Guide	
Shower Head	Manufacturer	Flow Rate GPM
Act-O-Matic	Sloan Valve	5.5
Boyd	American Std.	9.5
Victor	American Std.	10.0
Anystream No. 1 52240	Speakman	4.5
Anystream No. 2 52240	Speakman	4.5
Anystream No. 1 52250	Speakman	9.0
Anystream No. 2 52250	Speakman	7.0
Anystream No. 3 52250	Speakman	6.0
Brown 620-B	Chicago Faucet	8.0
Bubble Stream	Wrightway Eng.	4.0
Central Brass No. 3033	Central Brass Mfg.	3.0
Chase 188-355	Chase Brass & Copper	10.0
Crane Rainbow No. 8-2556	Crane Co.	5.5
Crane Capri 8-2550	Crane Co.	3.0
Crane Crestmont 8-3592	Crane Co.	3.0
Crane Crestmont 8-3590	Crane Co.	3.0
Crane Criterion 8-1561	Crane Co.	5.5
Dearborn	Dearborn Brass	7.5
Eljer	Eljer	6.0
Federal	Federal Huber	--
Gyro-Manystream	Gyro Brass Mfg.	--
Harcraft E-2	Harvey Machine	8.0
Homart 2091	Sears	--
Homart 2080	Sears	--
Indiana Brass	Indiana Brass Mfg.	--
Kohler K-7325	Kohler	--
Kohler K-7332	Kohler	--
Magic Fountain	Magic Fountain	2.8
Milwaukee "Premier"	Milwaukee Faucet	3.5
Sterling S-194	Sterling Faucet	6.0
Sure Flow 35	Sure Flow Brass Mfg.	3.0
Sure Flow 36	Sure Flow Brass Mfg.	4.5
Symmons Clear Flow	Symmons Eng.	3.5-7.0
Symmons Super Flow	Symmons Eng.	4.0-9.0
Universal/Rundle	Universal/Rundle	--
Wizard	Logan Mfg.	3.5-5.0
PP-15-020	Price Pfister	4.5
Morn 1533	Std. Screw	4.0

Source: Commercial Water Heaters: Electric Engineering Handbook. State Stove and Manufacturing Co., Inc., Ashland City, Tenn.; Henderson, Nevada.

Attachment B **Shower Water Use Data**

Name	Affiliation	Quantity of Water	Date
Jeff Millstein	FEA	29 gallons/shower	12/2/74
Kenneth T. Cuccinelli	AGA	35 gallons/shower	12/14/74
William Sharpe	Penn State Water Resource Extension Specialist	80 gallons/day/home for all bathing	-
William Barnes	Colonial Williamsburg	31 gallons/shower (5 minutes)	-
Ester Kweller	NBS	15-20 gallons/shower at heater	14/17/74
John C. Clark	Cornell U. School of Hotel Admin.	31 gallons (5 min)	10/73
Allan Feinberg	Beacon Valves	30 gallons/shower (5 minutes)	1/30/75
D.K. Todd (Editor)	Water Encyclopedia	30-60 gallons	1970
	N.Y. Dept of Water Supply - Information Services	15-25 gallon/shower	

Attachment C **Savings Through Use of Shower Flow Restrictors**

Name	Affiliation	Savings
William Sharpe	Penn State	50-70% savings 2000/gallons/person/year or 5.5 gallons/person/day
William Barnes	Colonial Williamsburg	16 gallons/shower 2.5 showers/room/day 6 GPM reduced to 2½ GPM. No guest comment. 2.4 showers per day in average home.
Alan Feinberg	Beacon Brass	15 gallon/shower
John C. Clark	Cornell U. School of Hotel Admin.	18 gallons/shower x 2 showers/per day per occupied room
	District of Columbia Government - Dept. of Environmental Service	Can cut shower water use in half
James R. Bailey	General Dynamics-Electric Boat Div. in report for S Dept. of Interior	6 GPD/capita or 24 GPD in a 4 member household
	Washington Suburban Sanitary Commission	50 GPD/home December 30 GPD/home January (test of 25 single family homes)

APPENDIX

Energy Savings Resulting from Installation of Shower Flow Restrictors in America's Homes

Introduction

Residential water heating accounts for a fuel consumption of 1,100,000 BPD oil equivalent or about 3 percent of all energy consumed in the United states. The National Bureau of Standards reports that bathing accounts for 42 percent of the total daily usage of hot water in a residence. Showers are perhaps the most popular form of bathing.

The energy equivalent of about 3 cups of fuel oil is consumed in a typical hot shower, thus a sizable reduction in the nation's use of energy can be obtained by reducing the amount of hot water used in showers. The reduction in hot water use can be accomplished by urging citizens (a) to install a flow restrictor to limit the shower flow rate, and (b) to reduce the duration of the time spent in the shower. It is not appropriate to recommend that people take fewer showers or reduce the water temperature selected.

Estimating the savings achievable is difficult because little is known about the country's showering habits. There is evidently a wide range of practices. Some individuals shower at least once a day, some never, preferring a bath instead or simply foregoing any body washing. The very old and the very young take baths in lieu of showers.

The temperature of the water as it arrives from the typical shower is uncertain. A water heater manufacturer places it as about 115°F. Others say about 105°F.

Some individuals are in and out of their shower quickly. Others, particularly teenagers, remain in the shower for 20 minutes or longer. A 5-minute duration is often taken as typical.

There is uncertainty, too, about the flow rate through the showerhead. Some individuals open wide the valve in the line to the showerhead, some open it only part way. Flow rate is a function of water pressure and that varies from one water system to the next. On the same system, it varies from one water system to the next. On the same system, it varies from one home to another. Even when the valve is wide open, the flow rate for the various makes of shower head at the same pressure varies greatly - the accompanying table shows 3 GPM for a Crane Crestmont Model S-359-2, for example, to 10 GPM for Chase Brass No. 3033. Flow rates as high as 18 GPM have been reported. See Attachment A.

In the Water Encyclopedia published by the Water Information Center, it is said that a shower bath requires 30-60 gallons of water. In the case of a shower head flowing at 6 GPM, this quantity might be consumed in 5-10 minutes.

It has been reported (ASHRAE Guide and Rate Book - Applications 1966-1967 page 982) that the "manufacturers maximum flow rating can usually be reduced up to 50 percent without adversely affecting the spray pattern of the shower head".

By installing a flow control device in the shower head the flow rate can be cut to 3 gpm, and by educational programs most individuals can be taught to keep showers down to 5 minutes or less. Thus, the water use for an average shower can probably be held to 15 gallons.

It is appropriate to evaluate the effects of a reduction in hot water usage for showers on a typical family and on the nation.

Assumptions

Let us assume that:

(a) the average number of hot showers taken daily in each shower equipped home is 2

(b) for each shower use a hot water saving of 10 gallons is achieved

Note: assumptions (a) and (b) together imply a 20 GPD Savings in water use per household. Data bearing on the reasonableness of this critical number appear. See Attachment B.

(c) the annual average temperature of the water in the mains is 60°

(d) the temperature of the water used in a hot shower by the average person is 105°

(e) 85% of all homes with gas or oil hot water heaters have one or more showers. 95% of all homes with electric hot water heaters have showers.

(f) there are 44 million homes equipped with a water heater fired by gas or oil (1970 Census data)

(g) there are 16 million homes with electric hot water heaters (1970 Census data)

(h) 11,600 BTU of fuel must be burned at the power generating station to produce and deliver to the home 1 kWh

(i) 1/3 of America's electricity is derived from oil or gas

(j) for a change in water demand, the efficiency of a gas or oil fired hot water heater can be taken as 50 percent

(k) for a change in water demand, the efficiency of an electric hot water heater can be taken as 100%; the reduction in hot water usage for showers has no effect on heat loss from tank jacket

(l) electricity with local taxes costs 3.0 cents/kWh

(m) oil costs 40 cents/gallon

(n) gas with local taxes costs $1.50 per million BTU, or $1.50 per therm.

(o) the heating value of distillate is 138,200 BTU/gallon

Savings Actually Realizeable

Of course, this potential probably cannot be fully realized because it is not possible to install a flow restrictor in every shower head. In some homes shower flow restrictors have already been installed or will have been installed by the time the embargo occurs.

In other homes the occupants would simply not install the flow restrictors:

> They may not know how to do it or may lack the necessary self-confidence. Or may fear that their shower would be less satisfactory. Or may be generally reluctant to try something new. Or they may not be inclined to take any action that

increases the landlord's profits. (In 1970 64 percent of the housing were owner-occupied. 36 percent renter-occupied. Compliance would not be the same for the two types)

It should, however, be possible to design a mandatory program which would bring about installation of flow restrictors in 75 percent of America's homes. If this were done, the oil and gas savings would exceed 80,000 BPD. And this number is based upon 1970 data when there were only 63.4 million occupied housing units. For an embargo occurring in 1977 with an inventory of 75 million homes, say, the actual savings for the residential sector could reach 95,000 BPD.

The savings obtainable through installation of flow restrictors in hotels, motels, schools, and other institutions would possibly bring the total savings up to the 100,000 BPD requirement.

Attachment D

Savings Obtainable Through Use of Flow Restrictors in Shower Heads

In the accompanying calculations a savings of 20 GPD per household is assumed as obtainable through installation of a flow restrictor in each shower head coupled with a public educational campaign urging that hot showers be kept short, i.e., to five minutes or less. To evaluate the reasonableness of this savings, a comparison with the only published data found on the subject is in order.

A year ago a test was run by the Washington Suburban Sanitary Commission on 25 single-family homes fitted with 40 Dole brand shower flow restrictors which limited flow rate to 3.0 gpm . Duration of showers was not controlled. Sizable water savings were observed. In December the average savings per household was 50 GPD, and in January 30 GPD. More savings might be expected in warm weather seasons when people take more showers, the WSSC report observed.

The U.S. Department of the Interior - Federal Water Quality Administration published in December 1969 a report prepared by James R. Bailey, et al, of General Dynamics Electric Boat Division entitled "A Study of Flow Reduction and Treatment of Waste Water from Households." The emphasis was on homes not connected to central sewerage systems. In this report limiting flow valves for showers were discussed. It noted that some claimed a 50-70 percent saving in shower water use. For their own calculations the authors selected a figure of 6 GPD per capita, or a saving of 24 gallons per day in a 4 member household. Here again the savings figure arrived at does not reflect reduced shower durations.

Development of hard data on the amount of hot water saved through use of a flow restrictor is most desirable.

The Impact of Water-Saving Devices on the Water Supply and Drainage Systems Within Buildings—A Preliminary Assessment

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Water saving fittings, fixtures, and other devices influence the magnitude of the demand, the volume of water consumed, and in some instances may affect the performance of the drainage system. In this paper we will examine the significance of this influence on the plumbing systems within multi-family and commercial buildings. The assessment must be regarded as preliminary because of the paucity of data on parameters, such as the frequency of use, and the limited knowledge of the complex multi-phase flow in the drainage system.

A generally accepted analysis of the water used in residences today, along with an estimate of the water usage based on the implementation of commercially available water saving products, is shown in Table 1, Present and Projected Water Consumption for a Family of Four. * Among these products are water saving toilets, flow control devices and front loading automatic washing machines. Plumbing fixtures and appliances may be divided into two classifications: fixed volume and variable rate. Water closets, washing machines, dishwashers, etc. are fixed volume, the user has no control over the rate or volume of water used. Fixed volume fixtures account for as much as 64 percent of the water used in homes equipped with dishwashers and automatic laundry equipment. Variable rate fixtures such as lavatories and sinks account only for a small part of the total water consumed in residences.

Table 1
Present and Projected Water Consumption
by a Typical Family of Four

Function	Current Use (gal)	Projected Use (gal)
Dishwashing	15	11
Cooking/Drinking	12	12
Utility sink	5	3
Laundry	35	24
Bathing	80	50
Lavatory	8	4
Water Closet	100	64
Total	255	168

Impact on Water Supply System

The demand for water within buildings is influenced by the average flow rate, the duration of use, the volume used per fixture operation and the frequency of use. The most widely used procedure for estimating the demand is the Hunter Method (1) which assumes a large number of fixtures and that the operation of the fixtures is a random event. Building on the fundamental concept that the probability of finding one particular fixture in operation at any given instant is $P = t$ — T where t = duration of use and T = frequency of use, Hunter developed the general expression;

$$P_n^r = \binom{n}{r}(1-p)^{n-r}p^r$$

where p_n^r = the probability of r fixtures operating from n fixtures at any given instant.

$\binom{n}{r}$ = the number of ways r fixtures can be selected from a collection of n fixtures.

$(1-p)^{n-r}$ = probability of (n-r) fixtures not operating at any given instant.

p^r = probability of r fixtures operating at any given instant.

In converting this relationship to a useful tool, Dr. Hunter established the criterion that for an adequate system the design load should not be exceeded more than 1 percent of the time permitting the determination of the number of fixtures, m, out of the total number of fixtures, n, that will probably not operate simultaneously more than the selected failure factor. It follows that the demand load, $Q = mq$ where q is the volume rate of consumption of a single fixture.

At this point in the development of his computational procedure Dr. Hunter directed his attention to a method of determining the expected demand for mixed systems. We suspect that the generalization of his theory was restricted by the computational limits imposed at the time of the development. As an alternative, Hunter developed the fixture unit concept which provides a computational procedure for estimating the demand for mixed systems. It assumes the ratio of the load factors for different fixtures is independent of the demand. The familiar Hunter Curve is shown in Figure 1.

In an earlier study (2) we developed an alternate Hunter Curve based on current fixture flow rates and frequency of use factors. This curve, also shown in Figure 1, provides for a significant reduction in the expected demand. It is based on the characteristics and parameters shown in Table 2. We are planning a field study to explore these parameters further.

Table 2
Parameters Used in Developing Alternate Hunter Curve

Fixture	Frequency of Use, t (sec)	Duration of Use, T (sec)	$P = \frac{t}{T}$	Average Flow (gpm)
W.C., valve	1200	9	.0075	27
W.C., tank	1200	90	.075	3
Lavatory	1200	60	.050	2
Bathtub	3600	300	.083	6
Sink	1200	45	.0375	4

As a case study, we used this alternate curve to determine the savings that may result from the improved knowledge by comparing the design pipe sizes for a 30-story apartment building. We concluded that savings in material and labor used for constructing the water supply risers and mains could be achieved. These savings range from 5 to 20 percent for the labor and 10 to 40 percent for materials, depending upon the particular design and demand load. Two examples are shown in Figures 2A, 2B, 3A, and 3B.

In another study (3), we explored the significance of several of the many parameters that influence the demand. The expected range of the parameters are shown in Table 3 and the specific cases investigated are shown in Table 4. In conducting this sensitivity analysis we used the general expression of Hunter and varied only one parameter in each case. Several examples from the report follow.

Case 1 - Bathtub

The frequency of use and the volume have been held constant at T = 3600 seconds and V = 20 gallons and the rate of supply assigned values of 4, 6 and 8 gpm (.25, .38 and .50 l/s). The results are shown in Figure 4. It may be seen that the estimated demand is influenced by a small amount for a significant change in q. At n = 200, a 50 percent increase in rate of flow results in a 12 percent change in the estimated demand.

Case 2 - Water Closet

With the consumed volume held constant at 5 gallons and the duration of use fixed at 60 seconds, the frequency of use was set at 600, 1200 and 1800 seconds. The results are shown in Figure 5. Again, it may be seen that the estimated demand depends strongly on the frequency of use value.

Case 3 - Water Closet.

In this case where T and t and therefore p are held constant, which may resemble a change to reduced volume water closets, there will be a well-defined change in the estimated demand equal to the percent reduction in volume. See Figure 6.

On the basis of the data and analysis obtained in this study, we concluded:

1. The frequency of use is the most critical parameter in the mathematical model used in computing the estimated demand.
2. The flow rate is not a significant factor and as a further result detailed attention need not be given to the particular style or manufacture of the fixture.
3. The volume consumed is intermediate in importance with respect to the estimated demand.

Table 3
Range of Parameters
Explored in Sensitivity Study

Fixture	Volume gal	Duration of Use seconds	Frequency of Use seconds	Flow Rate gal/min
Tub	15/20/25		1800/3600/5400	4/6/8
Water Closet (tank)	3.5/5	60/90	600/1200/1800	
Water Closet (valve)	4/6/8	8/10/18	600/1200/1800	
Lavatory		30/60/120/240/480	600/1200/1800	0.5/1/2
Sink	5		1200/1800	4/6
Sink		15/30	60/90	1/2/3/4

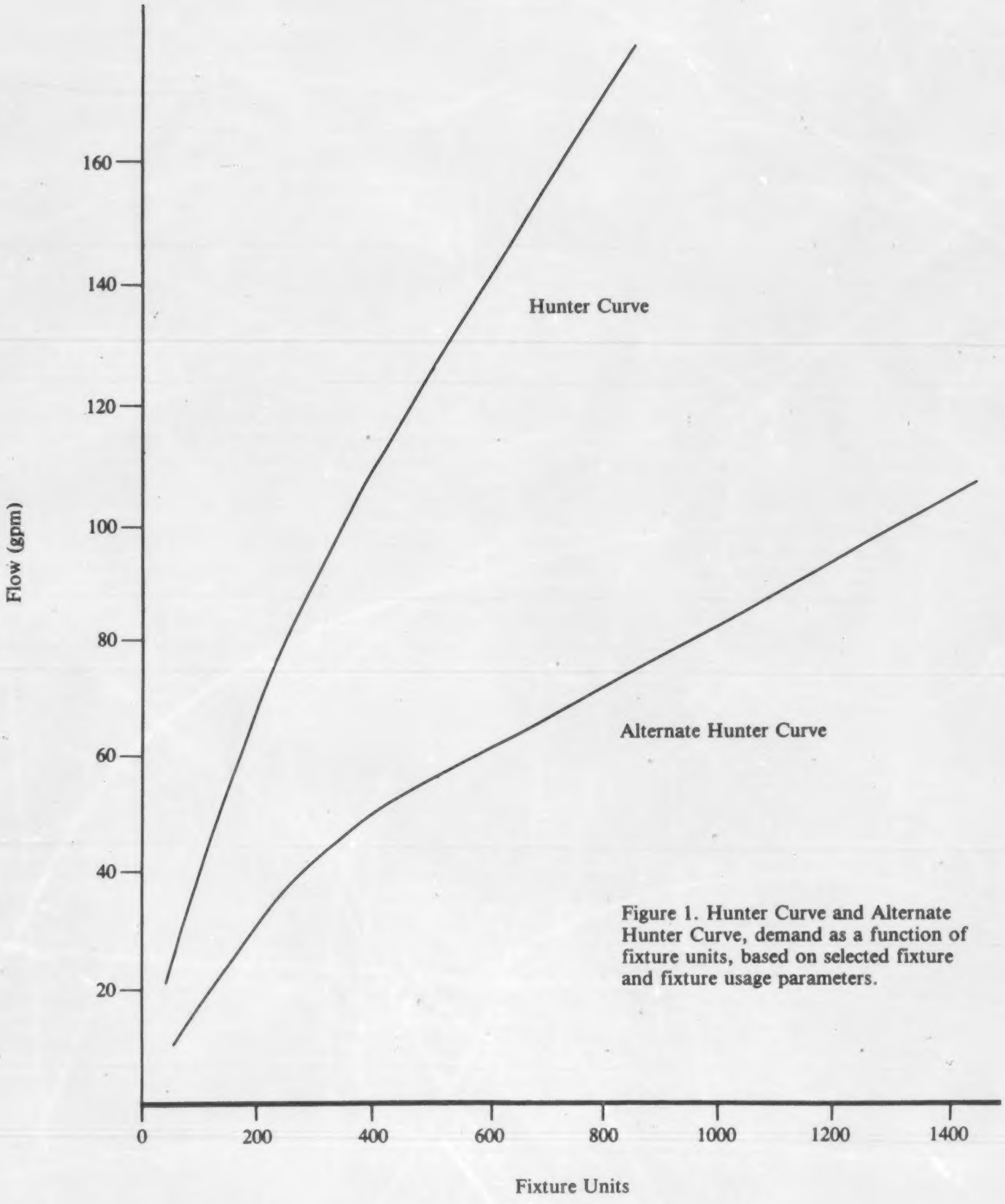

Figure 1. Hunter Curve and Alternate Hunter Curve, demand as a function of fixture units, based on selected fixture and fixture usage parameters.

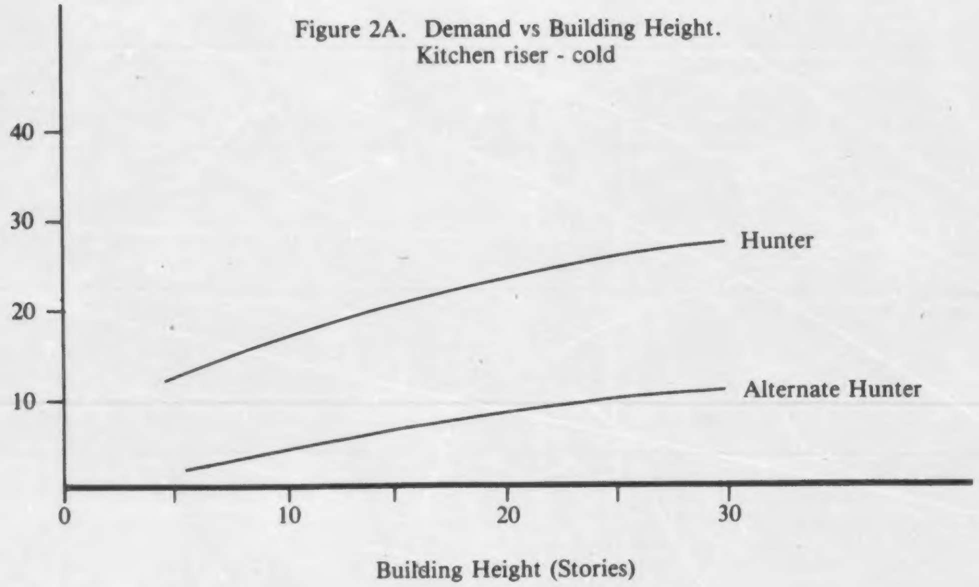
Figure 2A. Demand vs Building Height.
Kitchen riser - cold

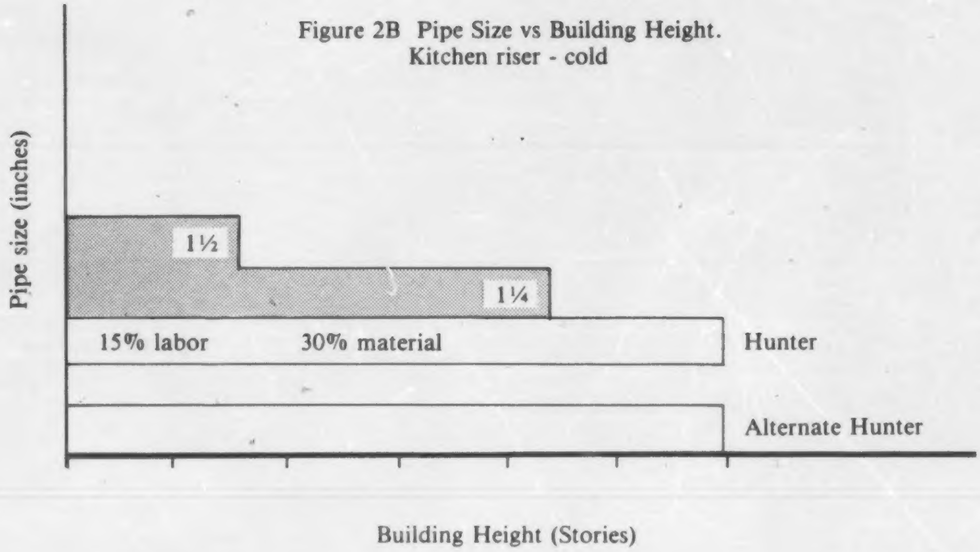
Figure 2B Pipe Size vs Building Height.
Kitchen riser - cold

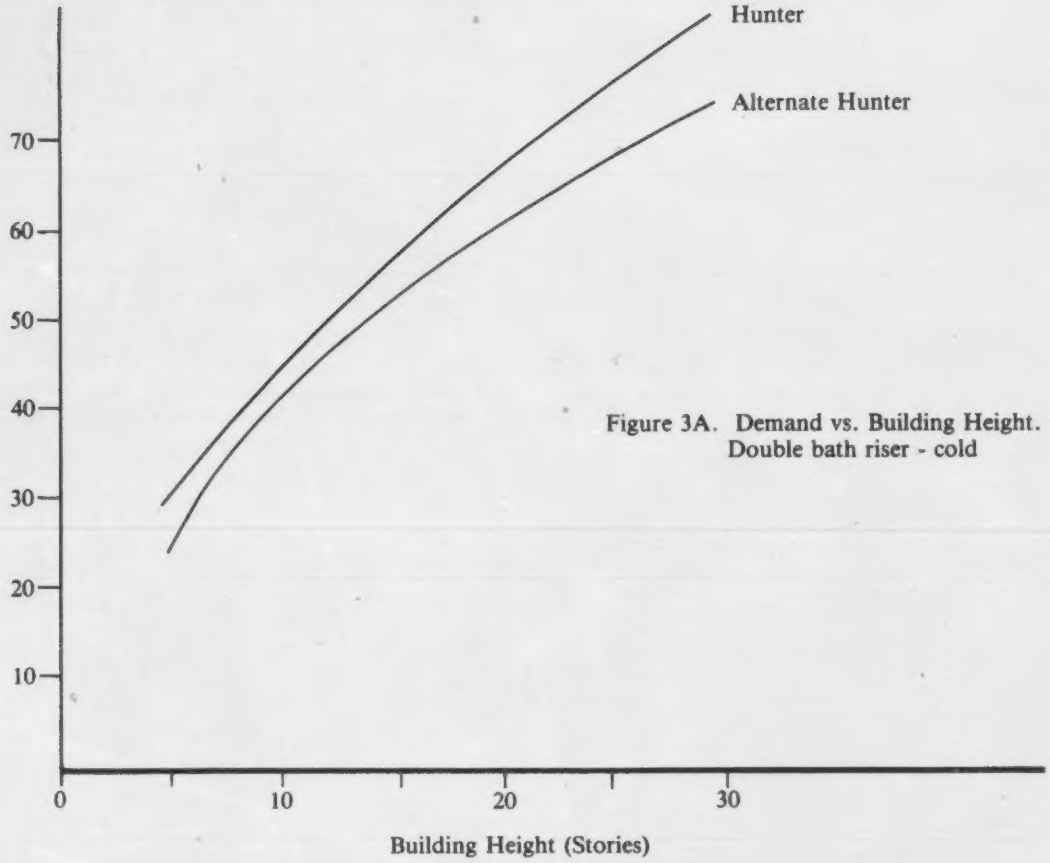

Figure 3A. Demand vs. Building Height.
Double bath riser - cold

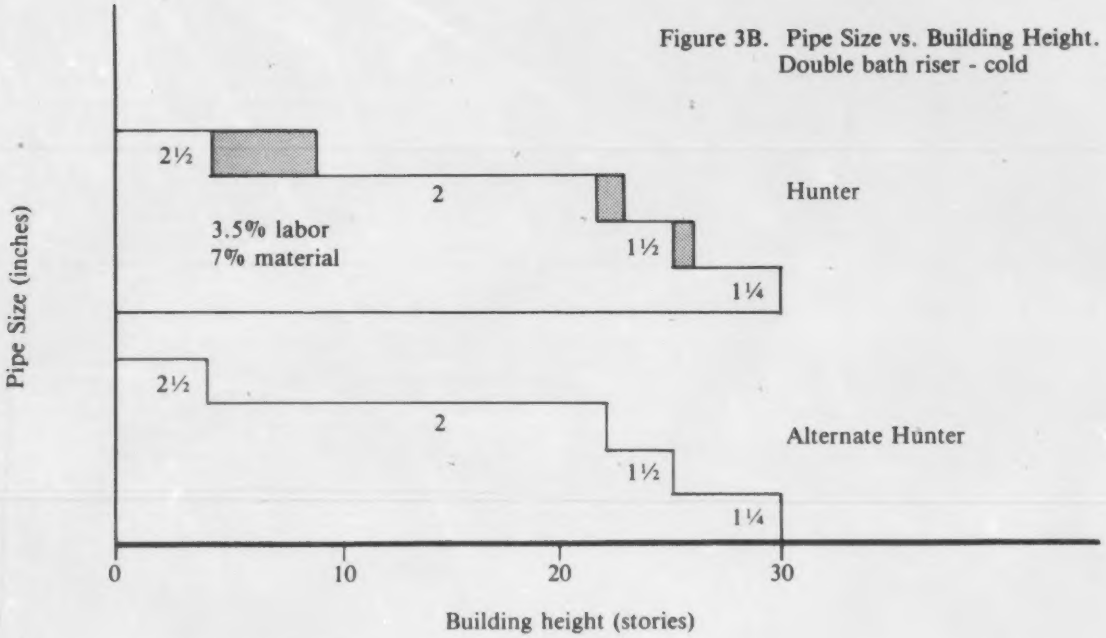

Figure 3B. Pipe Size vs. Building Height.
Double bath riser - cold

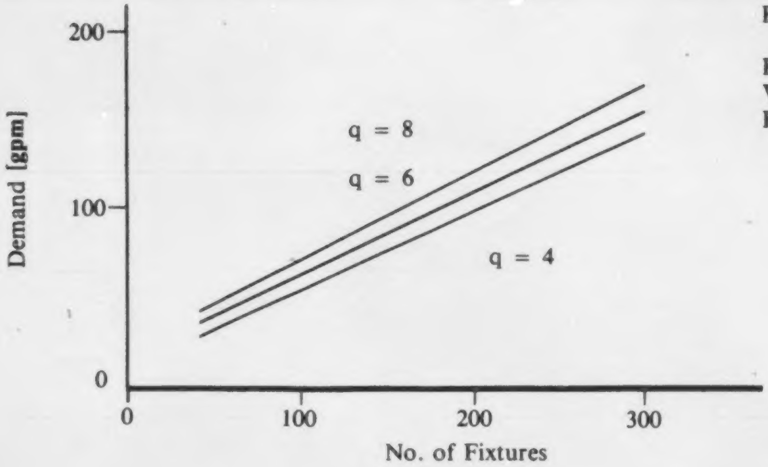

Fig. 4. Case 1 - Bathtub

Frequency of use - 3600
Volume - 20 gal
Flow rate - 4 gpm
6 gpm
8 gpm

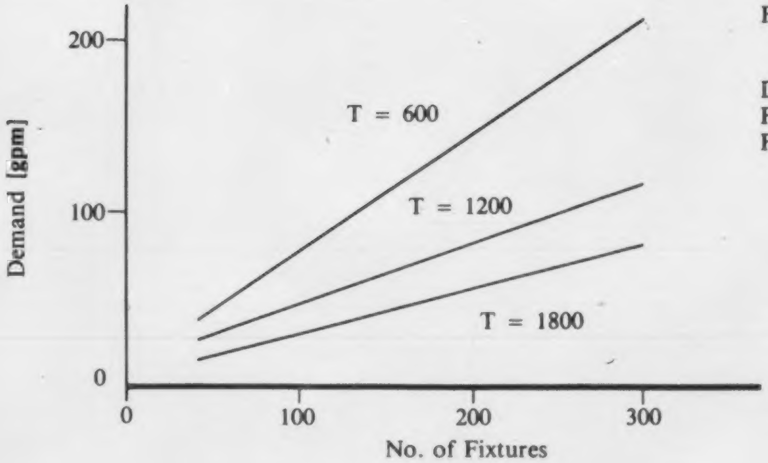

Fig. 5. Case 2 - Water Closet (tank)

Duration of use - 60 sec.
Flow rate - 5 gpm
Frequency of use - 600 sec
1200 sec
1800 sec

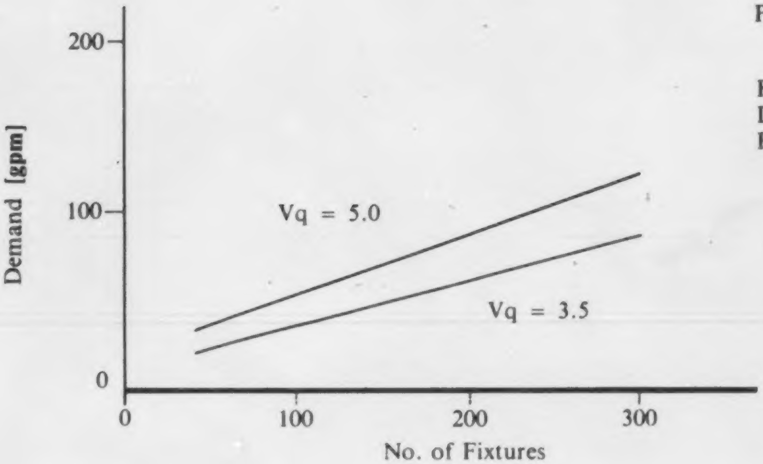

Fig. 6. Case 3 - Water Closet (tank)

Frequency of use - 1200 sec
Duration of use - 60 sec
Flow rate - 3.5 gpm V = 3.5 gal
5.0 gpm V = 5.0 gal

Table 4
Specific Cases of Interest

Case No.	Fixture	Parameter Investigated	Parameters Held Constant	
1	Tub	Q = f (T)	V = 20	q = 6
2	Tub	Q = f (q)	T = 3600	v = 20
3	Tub	Q = f (v)	T = 3600	Q = 6
4	W.C. (tank)	Q = f (T)	V = 5	t = 60
5	W.C. (tank)	Q = f (v)	T = 1200	t = 60
6	Sink	Q = f (T)	V = 5	q = 4
7	Sink	Q = f (q)	V = 5	T = 1200

Impact on Gravity Drainage System

The function of the drainage, waste, and vent system, DWV System, is to collect spent water from the various plumbing fixtures and to convey waste water to the public sewer or other disposal area in a safe and efficient manner. A safe manner implies collection and transmission with the emission of sewer gases, foul odors, or suds to the inhabitable area of the building. Traps at the entrances to the DWV system provide water seals to prevent the escape of sewer gases, odors, and suds. Most plumbing codes have been written with the intent of limiting the pressure fluctuations to plus or minus 1 inch of water under the design load conditions, thereby protecting the trap seal. An efficient manner means conveying the waste water and suspended solids without blockage. The generally accepted criteria to ensure this performance characteristic is to size the horizontal drainage lines such that the velocity is approximately 2 ft/sec. The efficient transport of waste, however, is a function of both velocity and depth of flow. If the depth is not sufficient, solids will settle out or encounter additional resistance through contact with the pipe walls.

The rate at which water exits from plumbing fixtures changes continuously. In the case of water closets, the discharge begins a few seconds after the flush is started and rises typically to a peak rate of 30 gpm, remains constant for a few seconds and then gradually falls off to a trickle flow before stopping. A complete cycle takes about 13 seconds. See Figure 7.

The discharge time for a lavatory is approximately 12 seconds and the peak flow rate is about 10 gpm. See Figure 8. The low flow rate and short duration suggest that lavatories have only a small influence on the hydraulics of the DWV system.

The bathtub discharge is influenced significantly by the geometry of the outlet piping. Typically, the rate of discharge rises to 12 gpm almost instantly and thereafter decreases continuously as the tub drains. It is important to note the length of time required to empty the tub, in this example, it is 140 seconds. The longer a fixture takes to drain, the more likely a second fixture will drain with it simultaneously. A typical discharge curve is shown in Figure 9.

The frequency, volume, and rates at which spent water enters the DWV system is of particular importance as combinations of these individual discharges make up the load imposed on the system. These factors will be discussed further where the expected number of fixtures discharging simultaneously and the corresponding flow are determined.

The flow in gravity drainage systems is very complex. It is often three phases; liquids, solids, and gases. It is non-uniform and unsteady. For these reasons, most of our knowledge is derived from actual tests on selected systems. There are, however, several fundamental concepts that we should be familiar with.

The flow in horizontal drainage pipes is classified as separated flow as the drain is generally only partially filled. The water flows along the lower half of the pipe, while air flows in the upper half, see Figure 10. The velocity and depth of the flow is constantly changing. As the volume of water increases the depth of flow increases displacing the air. When most of the normal air space is filled with water, the turbulence is high, and trap seals are disturbed. Horizontal drains are designed to flow half-full at capacity loads.

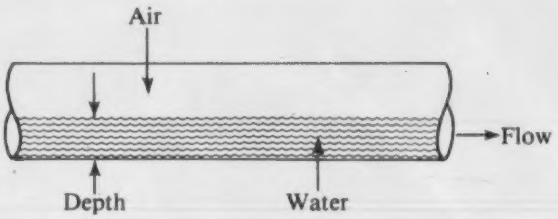

Figure 10. Flow in Horizontal Drain

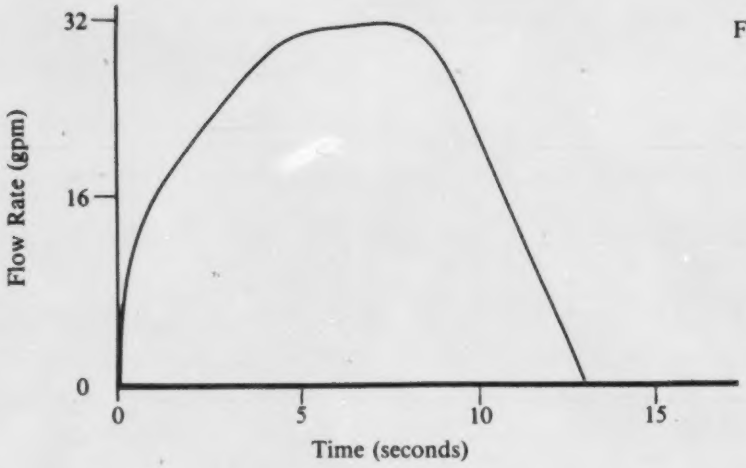

Figure 7. Hydraulic Characteristic-
Water Closet

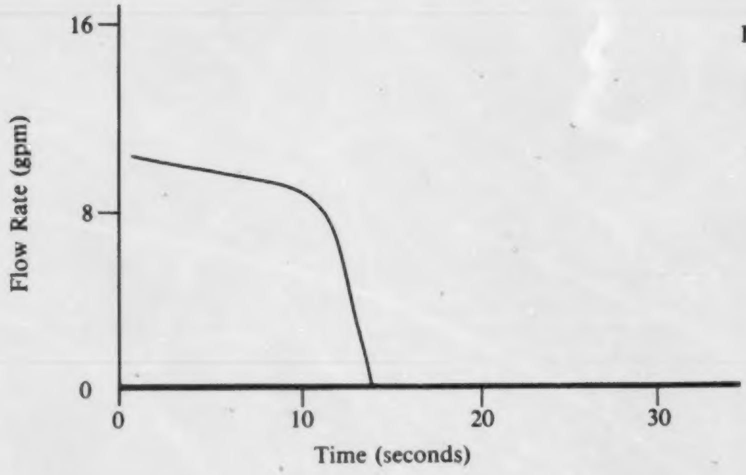

Figure 8. Hydraulic Characteristic-
Lavatory

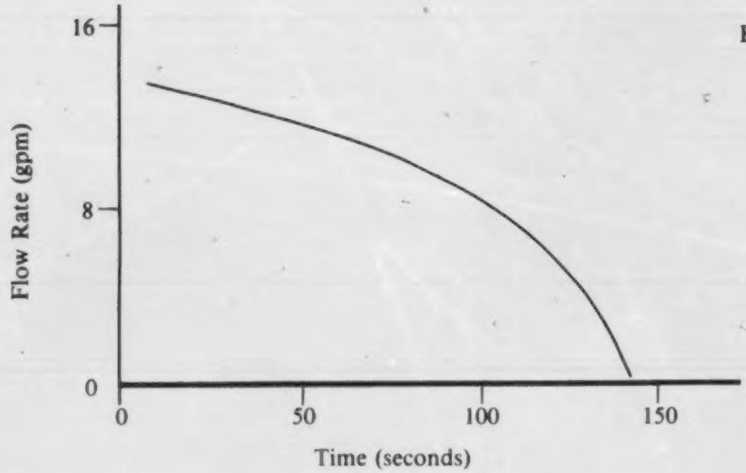

Figure 9. Hydraulic Characteristic-
Tub

64

The flow in vertical drains or stacks is entirely different. As water enters a stack it attaches itself to the wall of the pipe, forming an annulus. This cylinder of water falls down the pipe dragging air. See Figure 11. The establishment of the annular flow is rapid. Increasing the volume of water increases the water film thickness. When the volume of water occupies approximately 1/3 of the cross-sectional area of the stack the annual flow breaks down causing extreme turbulence and pulsations which result in the loss of the trap seals marking the capacity of the stack.

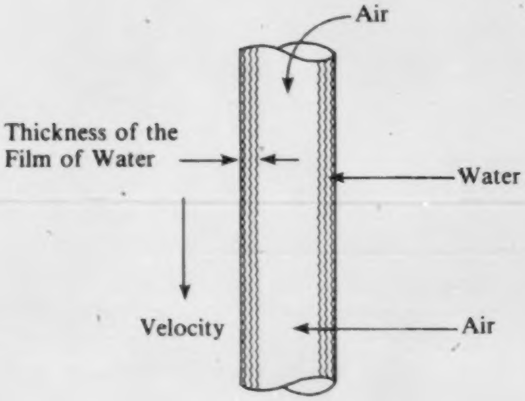

Figure 11. Flow in Vertical Stack

One of the most interesting areas in a drainage system is at the base of the stack. In this region the flow must change from the annular flow in the stack to the separated flow of the horizontal drain, see Figure 12. The disturbances at the base of stacks are often large and significant positive pressures are generated which, if not relieved, cause blowback. If the transition is smooth, much of the air is carried away through the horizontal drain.

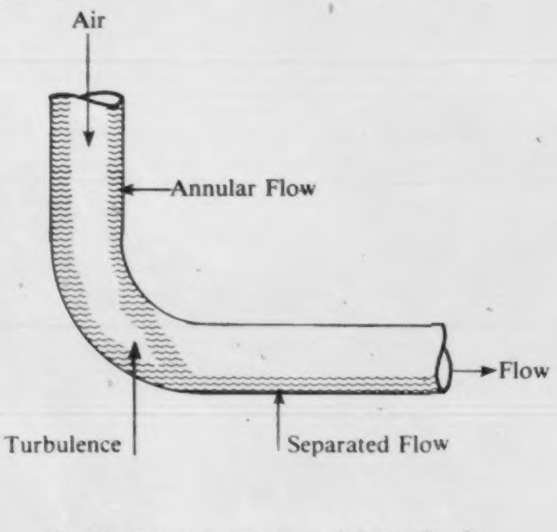

Fig. 12. Flow At The Base Of The Stack

Horizontal drains cannot transport the water at the same rate as stacks, the result is a phenomena called hydraulic jump. The change in velocity from aproximately 15 ft/sec in the stack to 2 ft/sec in the horizontal drain forces an increase in the depth of flow, resulting in a jump. In some cases, it is very abrupt and easily seen; in other cases it is merely a swelling. It has been our observation that this rise in the water level occurs much further downstream than the generally accepted 10-pipe diameters, approximately 3½ feet for a 4-inch drain. We have observed, in the immediate vicinity of the base of the stack, a washing of the sides of the drain which can cause temporary blockage of fixture drains or vents connected to the building drain near the base of the stack. Fittings rolled up to 45° are effective in avoiding problems in this area.

With this basic knowledge of the hydraulics of plumbing drainage system, we can begin a general assessment of the impact of water saving devices on the performance of the system. The two fixtures that have the greatest impact on the drainage system are: the water closet for its high rate of discharge and the bathtub for its medium discharge and long duration of use. The use of water saving equipment effects the discharge of the water closet but in no way influences the rate of discharge from the tub. Water saving water closets generally have a peak discharge value similar to conventional units. The duration of the peak, however, is somewhat less, see Figure 13. While a change such as shown in this figure will have an effect in the dynamic performance of a drainage system, it is not considered in the present analysis. As knowledge of the complex flows is assembled, we believe the dynamics of the system will have greater influence on the design.

The building drainage system consists of four areas with the flow appreciably different in each: horizontal branches, vertical stacks, primary drains, and secondary branches. The flow in horizontal branches which carries the discharge of fixtures to the soil stack has been discussed in an earlier report.(4) We found in this study that the velocity of the flow from spent water saving closets was slightly lower than that from conventional units but sufficiently high to indicate it unlikely for these typically short runs to be a problem area. Measured velocities were of the order of 3 to 4 ft/sec.

The waste water assumes the annual flow in vertical stacks and reaches a terminal velocity within a very short distance from its point of entry. Terminal velocities of 15 feet/second are typical in stacks and very few problems encountered. Other researchers (5) have reported that there is very little decay of the characteristic peaks which are the result of fixture discharges. Building drains, receiving the surging flow from the soil stack, are defined as primary drains when acting as a single drain connecting the base of the stack to the main building drain and secondary when acting as a collector for primary drains.

Many plumbing codes size primary drains on experimental work which assumes the building drain to be empty at the moment of peak surge and secondary branches as partly filled when subjected to the surge flow from fixtures. In the extreme case, long secondary branches, the flow approaches a steady condition and is governed by laws of open channel flow.

In this assessment we have limited our investigation to primary branches as part of a system receiving the discharge from water closets. Earlier researchers, (5) having explored this phenomenon experimentally, have found:

1) surge capacity increases as the duration of the surge decreases.
2) the effect of slope decreases as the duration of the surge decreases.
3) the effect of the duration of surge is smaller for larger slopes.

The fundamental result of their work, which forms the basis for the capacity tables found in plumbing codes, is shown in Figure 14. Hunter converted the complex form of the discharge curve to a simple form by fixing the peak velocity and determining a new duration of discharge for a constant volume of flush.

$$T = \frac{\text{Volume}}{\text{Peak Flow}}$$

A tabulation of the duration of the surge for water closets typical of the period when this work was completed, today's conventional units and water saving units is shown below.

Table 5
Duration of Surge for Water Closets

Water Closet	Volume (gal)	Peak Flow (gpm)	Surge Duration (second)
1940 Unit	4.0	30	8
Conventional	5.0	30	10
Water-Saving	3.5	30	7

The one second change in the duration of a surge results in a very small change in the capacity of the drain. As an example, consider a 4-inch drain at a slope of 1/4-inch per foot, for an 8-second surge duration the velocity is 4.6 ft/sec, for a 7-second surge duration the velocity is 4.7 ft/sec. Present technology cannot distinguish between these values which differ by 2 percent. It must be remembered that decreasing the duration of the surge increases the capacity of the system. What is important, and of greater concern, is the velocity and depth of flow in long primary branches and some secondary branches where the velocity and depth of flow resulting from the discharge of a single water closet may be low. However, even in this instance, the velocity and depth of flow appear reasonable, see Figure 14.

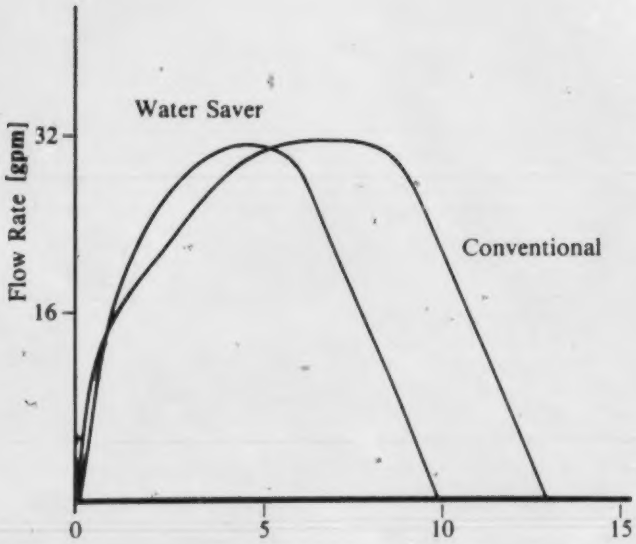

Figure 13. Water Closet Discharge Curves

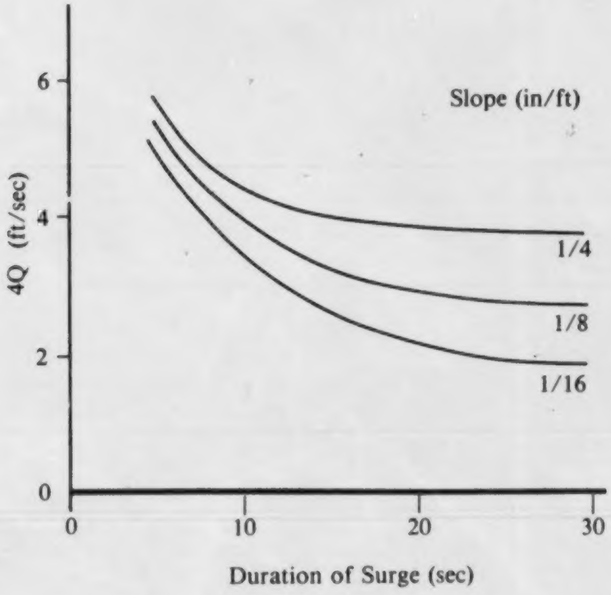

Figure 14. Surge Flow Capacity Data-4" Drain

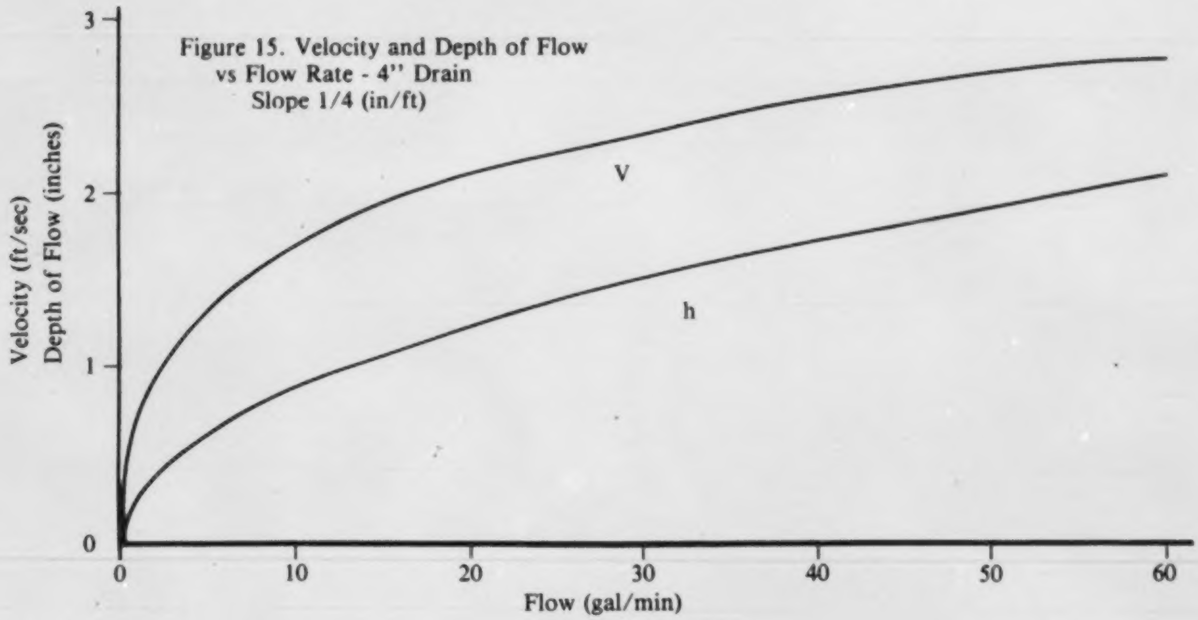

Figure 15. Velocity and Depth of Flow vs Flow Rate - 4" Drain Slope 1/4 (in/ft)

Conclusions and Recommendations

Sixty-four percent of the water used in residences is consumed through fixtures which are fixed volume appliances wherein the user has no control over the rate or amount of water required. While the rate and volume of water consumed through fixtures influence the demand, the frequency of fixture use is the most significant parameter. Unfortunately, the frequency of use is the parameter we know the least about and which is the most expensive to study in the field. It is obvious that the use of water saving fixtures and fittings will reduce the demand and volume consumed, it is also obvious that their use will increase the existing overdesign in our distribution systems. Research is needed to determine the safe economic quantities of water required for specific functions and acceptable performance of fixtures. Psychological and health factors must be considered in addition to the technical aspects.

The water closet and bathtub are the fixtures having the greatest influence on the drainage system. The use of water saving fixtures for the tub will not change the typical rate of discharge which is the input to the drainage system. Water-saving water closets have a peak discharge rate similar to conventional units. No additional clogging problems are expected as a result of this high rate of flow. In long horizontal drains where the surge is depleted, the low velocity and shallow depths of flow, characteristic of these areas, will be altered slightly. The present and projected conditions for transporting solids, while acceptable by current standards, can and should be improved. Mathematical procedures and /or simulation techniques should be developed to describe the system performance as a function of input.

Safe, efficient, and economical designs for water supply and drainage systems that will have a minimum impact on the surrounding environment can be achieved through continuing research. A full discussion of research needs in water supply and drainage is given in the proceedings (6) of the recent symposium on water supply and drainage held recently at the National Academy of Sciences, Washington, D.C.

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APPENDIX A

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Marlton, N.J. 08053

Walters, James
Dept. of Env. Protection
Div. of Water Resources
P.O. Box 2809
Trenton, N.J. 08625

Walton, Grant F. — Dean, Cook College
Rutgers University
Admin. Bldg.
New Brunswick, N.J. 08903

Ward, Harry
34 Winding Way
Cherry Hill, N.J. 08002

Ward, Juanita
34 Winding Way
Cherry Hill, N.J. 08002

Waskiewicz, John J.
650 E. Swedesford R.
Wayne, Pa. 19087

Wentz, Robert J.
106 West Edgewood Drive
McMurray, Pa. 15317

Whipple, William — Director
N.J. Water Resources Research Inst.
Cook College — Rutgers University
New Brunswick, N.J. 08903

White, Jane
P.O. Box 96
Franklin Lakes, N.J. 07417

Wieland, Robert George
N.J. District Water Supp. Comm.
Wanaque, N.J. 07465

Wilford, John — Asst. Director (speaker)
Water Supply & Flood Plain Mgmt.
Div. of Water Resources
NJDEP
Box 2809
Trenton, N.J. 08625

Yeatman, Henry
23 West Ridge Rd.
Toms River, N.J. 08753

Zsitkovsky, Robert K.
513 West Burk Ave.
Wildwood, N.J. 08260

APPENDIX B

ALPHABETICAL LISTING OF MANUFACTURERS AND DISTRIBUTORS OF WATER-SAVING DEVICES*

AERA-FILT SYSTEMS, INC.
P.O. Box 567
Lafayette, Indiana 47901
Sewerless toilet; diffused air, extended aeration unit

ALSONS PRODUCTS CORPORATION
525 E. Edna Place
Covina, California 91722
Hand held shower

AMERICAN STANDARD-PLUMBING/HEATING
Post Office Box 2003
New Brunswick, New Jersey 08903
Conventional toilets; conventional urinals; shallow trap toilets; conventional faucets; self-closing valves; pressure balancing mixing valve; shower fixture, Aquarian (4 gpm) flow control Aquamizer (2.5 gpm)

AQM CORPORATION
1909 New Rodgers Road
Levittown, Pennsylvania 19056
"Aqua-miser" toilet tank insert

AQUA-DATA CORPORATION
P.O. Box 901
Carpinteria, California 93013
Drip irrigation

AQUA GUARD
3200 Valley Lane
Falls Church, Virginia 22044
Toilet tank insert (see mini-Dam)

AQUA-GUARD POOL COVERS
2801 San Fernando Road
Los Angeles, California

AQUA MISER
P.O. Box 284
Glen Ellen, California 95442
Aqua miser toilet tank insert

ARROWHEAD PURITAS WATERS
1566 East Washington
Los Angeles, California 90054
Bottled water

BEACON VALVE COMPANY
Walthaur, Massachusetts
Flow Reducing Valves

BIO SYSTEM
1200 28th St., Suite 1
Boulder, Colorado 80802
Evapotranspiration home sewage treatment and disposal systems.

BRIGGS
5200 West Kennedy Boulevard
P.O. Box 22622
Tampa, Florida 33622
Conserver, shallow trap toilet; conventional toilets; bidet.

BUDERUS
6330 Wetzlar
Postfach 201
West Germany
Water-saving tub

CAN-TEK INDUSTRIES
Process Equipment Division
P.O. Box 340
Mineral Wells, Texas 76076
Large aerobic treatment plants

CHAPIN WATERMATICS, INC.
368 N. Colorado Avenue
Watertown, New York 13601
"Micro-Dripper". Drip irrigation emitter, direct tap into polyethylene pipe.

CHICAGO FAUCETS
2100 S. Nuclear Drive
Des Plaines, Illinois 60018
Econo-flow (0.75 gpm aerator) faucet; Soft-flo flow control; Stedi-flo flow control; self-closing faucets; conventional faucets.

CHRYSLER CORPORATION
Space Division
P.O. Box 29200
New Orleans, Louisiana 70129
Oil flush toilet

CLIVUS MULTRUN USA, INC.
14A Eliot Street
Cambridge, Massachusetts 02138
Composter toilet

COLT INDUSTRIES
Water and Waste Management Operation
701 Lawton Avenue
Beloit, Wisconsin 53511
Envirovac system vacuum toilet; Liljendahl, Electrolux.

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* Note: The inclusion of a company's name in this list does not in any way constitute an endorsement of its products.
Every effort has been made to check the accuracy and completeness of this listing. Any errors or omissions were not intentional.

CONSERVOCON, INC.
191 Edgewater Street
Staten Island, New York 10305
Foot controlled faucet ($9 attachment)

CONTROLLED WATER EMISSION SYSTEMS
585 Vernon Way
El Cajon, California 92022
Drip irrigation

CRANE COMPANY
17900 Skypark Circle
Irvine, California 92664
Shallow trap toilet; conventional toilet; conventional urinal.

CROMAGLASS CORPORATION
Box 1146
Williamsport, Pennsylvania 17701
Aerobic waste treatment tanks

CULLIGAN DEIONIZED WATER SERVICE
315 N. Hoover Street
Los Angeles, California 90004
Water filters

CUSTOM HOME SPA
14705 Oxnard Street
Van Nuys, California 91401
Whirlpool spa

DUPONT COMPANY
1007 Market Street
Wilmington, Delaware 19898
Drip irrigation

DEEP SEEP CAP-TOP SOAKERS
915 E. Bethany Home Road
Phoenix, Arizona 85014
Drip irrigation

DEFCO, INC.
325 North Daloson Drive
Camarillo, California 93010
Emitters for drip irrigation

L.M. DEARING ASSOCIATES, INC.
12324 Ventura Boulevard
Studio City, California 91604
Floating pool cover

DIXEL IRRIGATION SYSTEMS
17 Briar Hollow
Houston, Texas 77027
Drip irrigation - strap on emitter

DOLE (see EATON)

DUO-FLUSH PLUMBING COMPANY
610 S. Tejon
Colorado Springs, Colorado 80903
Two-way flushing valve

EATON CORPORATION
Controls Division
Plumbing & Heating Products
191 East North Avenue
Carol Stream, Illinois 60187
Dole flow controls (2,3,4, gpm); Dole shower controls (2,2.5,3,4 gpm); Dole sink faucets (1.5 to 4 gpm models).

ECOLOGICAL WATER PRODUCTS INCORPORATED (EWP)
P.O. Box 509
Dunkirk, New York 14048
Nova shower head (2.5 gpm); EWP faucet aerators (1.5 gpm).

ECODYNE CORPORATION
Smith & Loveless Division
96th & Old Santa Fe Trail
Lenexa, Kansas 66215
Aerobic sewage treatment, large units.

ECOLOGY PLUS
Box 184
Croydon, Pennsylvania 19020
Water wizard tank insert

ELECTROLUX
S-105 45
Stockholm, Sweden
Vacuum toilet

ELJER PLUMBING WARE
Wallace Murray Corporation
Three Gateway Center
Pittsburgh, Pennsylvania 15222
Savon water-saving urinal; shallow trap toilet; conventional urinal; conventional toilet.

RICHARD FIFE INCORPORATED
140 Greenwood Avenue
Midland Park, New Jersey 07432
Spray taps; flow control built into the faucet; Rada thermostatic mixing valve.

FLUIDMASTER, INCORPORATED
P.O. Box 4264
Anaheim, California 92803
Tank flushing valve, leak signaling ballcock.

FORMULABS INCORPORATED
Fluorescent Dye Tracing Systems Division
529 West Fourth Avenue - P.O. Box 1056
Escondido, California 92025
Water saver super drip kit; toilet tank dye tablet.

FRIEDRICH GROHE ARMATORENFABRIK
5870 Hemer, Postfach 260
Grohe Wien GmbH, 1071 Wiem
Postfach 285 West Germany
Thermostatically controlled mixing valve

GENERAL AMERICA TRANSPORTATION CORPORATION
General America Research Division
7449 North Natchez Avenue
Niles, Illinois 60648
Controlled volume flush toilet

A B GUSTAVSBERGS FABRIKER
Fleminggatan 62 B, Box 12159
10224 Stockholm 12, Sweden
Composter toilet

GENERAL ELECTRIC COMPANY
Denver, Colorado
"Suds Saver" clothes washer

HARGRAVE ENTERPRISES
121 Lake Highlander
Dunedin, Florida 33528
Digester Toilet

HUMUMAT LIMITED
9403 120th Street
Delta, British Columbia
Canada V4C 2P3
Composter toilet

HYDRO-RAIN
26031 Avenida Aeropuerto
San Juan Capistrano, California 92675
Solenoid valves for lawn sprinkling and irrigation.

HYDRO TERRA CORPORATION
800 North Park Avenue
Pomona, California 91768
Automatic irrigation controller tensiometers

HYDROLON SYSTEMS, INCORPORATED
1948 Gladwick
Compton, California 90220
Water filters

INTERBATH, INCORPORATED
3231 North Durfee
El Monte, California 91732
Hand-held shower

ITT LAWLER
453 North MacQuesten Parkway
Mount Vernon, New York 10552
Pressure reducing valve house connection

IDEAL STANDARD
Postfach 549
Poppelsdorfer Allee 114
53 Bonn
West Germany
Thermostatically balancing mixing valve.

INCINOMODE, INC.
Garland, Texas 75040
Incinerator Toilet

IN-SINK-ERATOR (I.S.E.)
4700 21st Street
Racine, Wisconsin 53406
Garbage disposal; instant hot water heater.

INTERNATIONAL METAL PRODUCTS
Division of McGraw Edison
Box 20188
500 South 15th Street
Phoenix, Arizona 85036
Evaporative air cooler

IRRI-DRIP SYSTEMS, INCORPORATED
870 East Santa Clara Street
P.O. Box AW
Ventura, California 93001
Drip irrigation

JACUZZI RESEARCH INCORPORATED
1440 San Pablo Avenue
Berkeley, California 94702
Whirlpool spa

JEF SKID
P.O. Box 2288
Rockville, Maryland 20852
Dual flush toilet

JEGCO, INCORPORATED
2016 Sunset Drive
Pacific Grove, California 93950
Gold-ring variable flush attachment

JENSEN GENERAL CORPORATION
1946 East 46th Street
Los Angeles, California
Chemical toilets

JKW 5000 LIMITED
10610 Culver Boulevard
Culver City, California 90231
Watergate toilet tank insert; Ny-Del shower head.

KEENE CORPORATION
Water Pollution Control Division
1740 Molitor Road
Aurora, Illinois 60507

KITCHEN AID
Hobart Manufacturing Company
1501 W. 8th Street
Los Angeles, California 90017
Instant hot water heater

KOHLER COMPANY
Kohler, Wisconsin 53044
Conventional toilet; conventional urinal; Water Guard shallow trap toilet; pressure balancing mixing valves; flow control shower heads (3 gpm and up); flow control faucets (2 gpm and up).

LAKESIDE EQUIPMENT CORPORATION
1022 E. Devon Avenue
Bartett, Illinois 60103
Large aerobic sewage treatment units

LAMERE INDUSTRIES, INCORPORATED
227 N. Main Street
Walworth, Wisconsin 53184
Destroilet, incinerator-toilet system.

LEISURE TIME WATERING SYSTEMS
P.O. Box 1298
Hollister, California 95023
Drip irrigation

LIFTOMATIC INCORPORATED
6445 N. Sepulveda
Los Angeles, California
Swimming pool covers

MANSFIELD SANITARY, INCORPORATED
Perrysville, Ohio 44864
Water-saver toilet flush valve; vacuum flush toilets for boats; chemical toilets.

THE MAYTAG COMPANY
17065 E. Green Drive
City of Industry, California 91744
Clothes washer

MERWIN MANUFACTURING INC.
P.O. Box 509
Dunkirk, New York 14048

METROPOLITAN WATERSAVING COMPANY, INCORPORATED
5130 MacArthur Boulevard, Suite 106
Washington, D.C. 20016
"Little john" water closet insert.

MICROPHOR
P.O. Box 490
Willits, California 95490
Microphor pressurized flush toilet (2 quarts per flush).

MILWAUKEE FAUCET, INC.
Milwaukee, Wisconsin
"Adjusto" Faucet

MINI-DAM WATERSAVER CORPORATION
640 S. Pickett Street
Alexandria, Virginia 22304
Toilet tank insert (See Aqua Guard)

MINUSE ENVIRO-SYSTEMS, INCORPORATED
206 N. Main Street, Suite 300
Jackson, California 95642
Shower (2 quarts per minute)

MOEN
Elyria, Ohio 44035
Pressure balancing valves; shower head, Easy-clean (3gpm). Aerators

MONOGRAM INDUSTRIES, INCORPORATED
100 Wilshire Boulevard
Santa Monica, California 90401
Oil flush toilet (Magic Flush); chemical toilet.

MONTGOMERY WARD & COMPANY
618 Chicago Avenue
Chicago, Illinois 60671
Appliances

MOONEY BROTHERS CORPORATION
195 Paterson Avenue
Little Falls, New Jersey 07424

MUEHLER BRASS COMPANY
Port Huron, Michigan 48060
Adjustable faucet

MULTI-FLOW, INCORPORATED
500 Webster Street
Dayton, Ohio 45401
Recycling extended aeration filtration unit

NATIONAI HOMES CONSTRUCTION CORP.
Airvac Division
P.O. Box 508
Rochester, Indiana 46975

NEPTUNE MICROFLOC INCORPORATED
P.O. Box 612
Corvallis, Oregon 97330
Community wastewater treatment

NOLAND COMPANY
2700 Warwick Boulevard
Newport News, Virginia 23607
Flow controls (plastic inserts)

M.C. NOTTINGHAM COMPANY
P.O. Box 2107
Irwindale, California 91706
Septic systems

NY-DEL CORPORATION
740 E. Alosta Avenue
Glendora, California 91740
The "Saveit" water closet insert

OGDEN FILTER COMPANY, INCORPORATED
4222 Santa Monica Boulevard
Los Angeles, California
Water filters

OSBY-PANNAN AB
28300 Osby
Sweden
Freeze toilet

OWENS/CORNING
5933 Telegraph Road
Los Angeles, California 90040
Hot water pipe insulation

PACEMAKER CORPORATION
3828 Fifth Avenue
San Diego, California 92103
Moisture indicator

PACTOSAN
Nitro Nobel Group
Box 100, S-71300 Nora
Sweden
Packaging toilet

PATRICK INDUSTRIES, INC.
Box 481
Altadena, California 91001
Water Saver Modification

PIPER HYDRO, INCORPORATED
1159 Fountain Way
Anaheim, California 92806
Combined domestic hot water circulation and heating system.

POLLUTROL TECHNOLOGY, INCORPORATED
32 Kearney Road
Needham Heights, Massachusetts 02194
Aerobic waste treatment

POWERS REGULATORY COMPANY
Skokie, Illinois 60076
Pressure balancing shower and bathtub valves

PROGRESSIVE HARDWARE
P.O. Box 874
Garden Grove, California 92642
Ballcock

RAIN BIRD
Glendora, California
Drip irrigation emitters

RESEARCH PRODUCTS MFG. CO.
P.O. Box 35 164
Dallas, Texas 75235
Incinolet Toilet

ROKAL ARMATUREN GMBTT
4054 Nettetal -1
Postfach 1266
West Germany
Thermostatically controlled mixing valve

RIVIERA SPA, INCORPORATED
11735 Sheldon Street
Sun Valley, California 91352
Whirlpool spa

SAVE IT OF WASHINGTON
11168 Safford Way
Reston, Virginia 22070
Toilet tank inserts (2 models)

SEARS ROEBUCK AND COMPANY
Sears Towers
Chicago, Illinois 60684
Water filters; chemical toilet; appliances, etc.

SOILMOISTURE EQUIPMENT CORPORATION
Box 30025
Santa Barbara, California 93105
Soil tensiometers

SLOAN VALVE COMPANY
Franklin Park, Illinois 60131
Flow Reducing Valves

SPARKLETTS DRINKING WATER CORPORATION
3475 LaCienega
Los Angeles, California
Bottled water

SPEAKMAN COMPANY
Wilmington, Delaware 19899
Flow controls, Auto flow (2.5 to 4.5 gpm); spring and time faucets; shower heads, Auto flow (2.5 to 4.5 gpm).

SPOT SYSTEMS, INCORPORATED
P.O. Box 807
Redmond, Washington 98052
Drip irrigation emitters

SUBMATIC IRRIGATION
P.O. Box 2449
Menlo Park, California 94025
Drip irrigation

SUNSET POOLS
900 Wilshire Boulevard, Suite 1242
Los Angeles, California 90017
Solar circles (floating swimming pool "solar heaters" and evaporation reducers).

TART INCORPORATED
500 Webster Street
Dayton, Ohio 45401

TE-BE ELPRODUKTER AB
Postbox 34
561 01 Huskoarna
Sweden
Freeze toilet

THETFORD CORPORATION
Waste Treatment Equipment Division
P.O. Box 1285
Ann Arbor, Michigan 48106
"Cycle-let" recycling flush waster toilet; chemical toilets

THROKOL-WASATCH DIVISION
P.O. Box 524
Brigham City, Utah 84302
Recirculating Toilet & Treatment system

TURF SERVICE LABORATORY
P.O. Box 1001
Laguna Beach, California 92651
Moisture indicators, moisturometer

TYME VALUE CORPORATION
12100 E. Park Street
Cerritos, California 90701
Sprinkler control

ULTRAFLOW CORPORATION
P.O. Box 2284
Sandusky, Ohio 44870
Electrically controlled plumbing system

UTAH MARINE
459 South Seventh Street
P.O. Box 485
Brigham City, Utah 84302
Flush Gard: sink-bob dual flush device

WAICO-NORTHWEST
5920 N.W. 87th Avenue
Portland, Oregon 97220
Drip irrigation

WALKER CROSSWELLER LIMITED
Whaddon Works, Cheltenham,
Gloucestershire, England
Spray taps (single or double handle)

WATER CONTROL PRODUCTS* INCORPORATED
1100 Owendale, Suite E
Troy, Michigan 48084
Flushmate pressurized tank toilet

WATER WIZARD, INC.
P.O. Box 184
Croyden, Pennsylvania 19020

WATER SAVE, INC.
3181 N.E. Third Ave.
Fort Lauderdale, Florida 33308
Econo Flush Modification

WATER SAVER
Croyden, Pennsylvania
"Dam-it" Modification

WATTS REGULATOR COMPANY
Lawrence, Massachusetts 08142
Water pressure reducing valve house connection

WESTINGHOUSE ELECTRIC COMPANY
Mansfield, Ohio
Water saving Clothes Washer

WRIGHTWAY MANUFACTURING COMPANY
371 East 116th Street
Chicago, Illinois 60628
Water-saver kit (shower head and two faucet aerators)

ZURN INDUSTRIES INCORPORATED
2267 Yates
Los Angeles, California
Chemical toilets